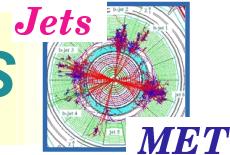




FE SIMULATION AND JETS/MET-RELATED ISSUES

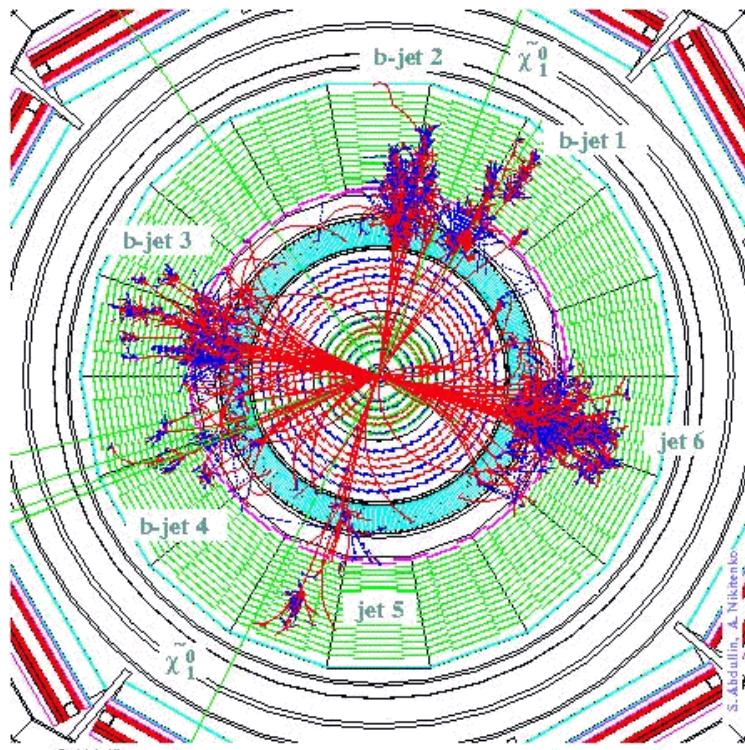
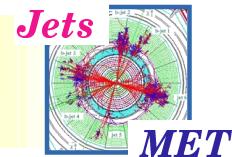


Salavat Abdullin, University of Maryland

- Progress on inclusive SUSY trigger at low lumi
- First look at the jet / di-jet resolution vs ECAL thresholds
- Update on HCAL FE simulation (new / old signal shape)



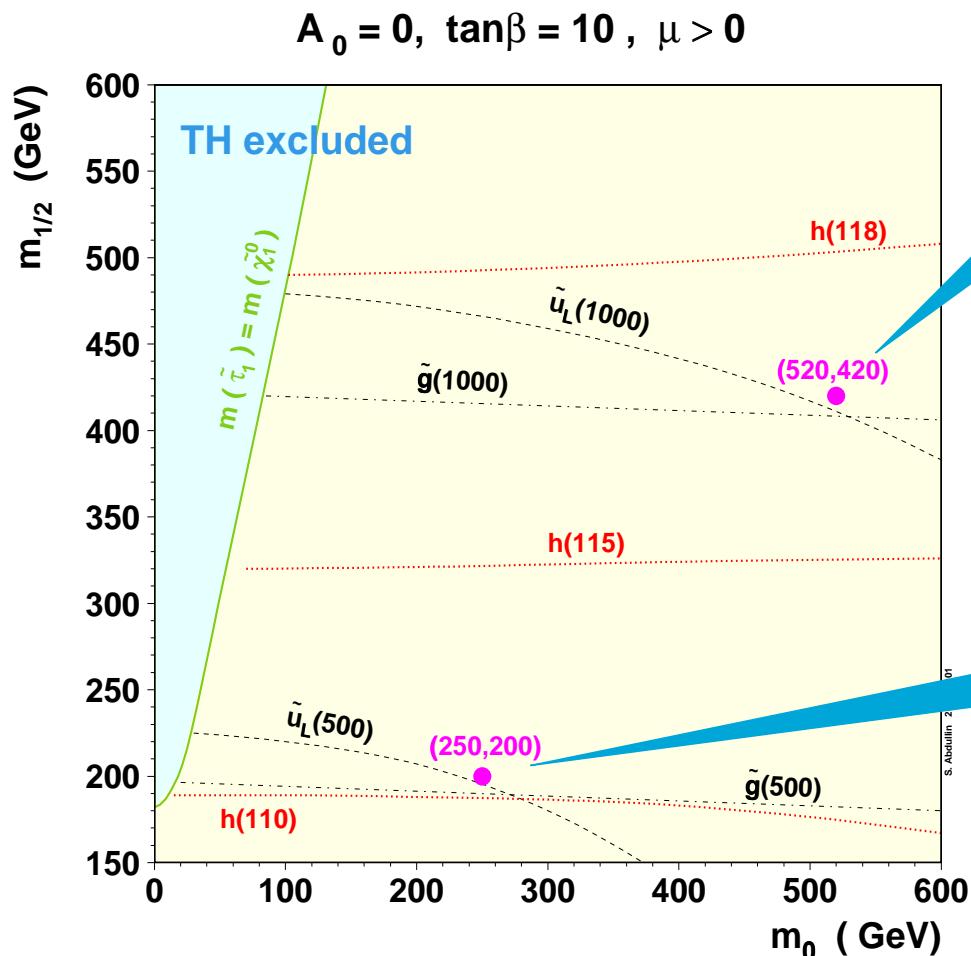
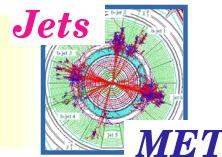
INCLUSIVE SUSY TRIGGER @ $2 * 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$



- Generic SUSY :
multijet + (leptons) + E_T^{miss} events
- Two mSUGRA points
are available for low-lumi study
 - $M_{\text{SUSY}} \sim 500 \text{ GeV}$ (beyond Tevatron II reach)
 $\sim 1000 \text{ GeV}$
 - $m(\tilde{g}) \approx m(\tilde{q})$
 - $\tan \beta = 10$ ("preferred")
 - $\mu > 0$ - the sign doesn't play a big role,
though positive one is favoured by g-2
"indirect" constraint - anomalous
magnetic momentum of muon



PROBING POINTS



$$m(\tilde{\chi}_1^0) = 177.5 \text{ GeV} \quad m(h) = 116.8 \text{ GeV}$$

$$m(\tilde{t}_1) = 726 \text{ GeV}$$

$$\sigma = 2.24 \text{ pb}, \text{ requires } \int L dt < 100 \text{ pb}^{-1}$$

typical cuts :

$$E_T > 300 \text{ GeV}, N_j \geq 4$$

$$E_T^j > 200, 100, 50 \text{ GeV}$$

$$m(\tilde{\chi}_1^0) = 79.0 \text{ GeV} \quad m(h) = 110.7 \text{ GeV}$$

$$m(\tilde{t}_1) = 352 \text{ GeV}$$

$$\sigma = 115 \text{ pb}, \text{ requires } \int L dt < 10 \text{ pb}^{-1}$$

typical cuts :

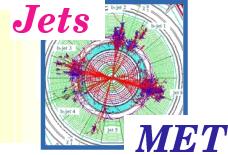
$$E_T > 200 \text{ GeV}, N_j \geq 3$$

$$E_T^j > 100, 50, 50 \text{ GeV}$$

■ Cuts efficiency for the signal : 20 - 50 % (0.5 - 1 TeV)



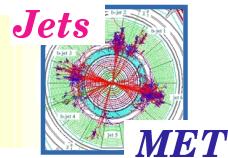
MORE PROBING POINTS ?



- Inclusive SUSY signatures (except some degenerate cases) have a kind of "compensating" effect due to multi-particle cascade decays
 - less jets \rightarrow harder jets
 - missing E_T slightly depends on internal mass hierarchy
(lighter $\tilde{\chi}_1^0$ \rightarrow more boosted etc.)
- After cuts optimization the observability of inclusive SUSY signal depends mainly on the mass scale of strongly interacting sparticles (squarks and gluino)



BACKGROUND



■ SM background for fairly low SUSY mass scale (0.5-1 TeV) :

- single(Wtb)/double top production,
multijet QCD (incl. $b\bar{b}$ + X),
 $W/Z + \text{multijets}$
- } comparable

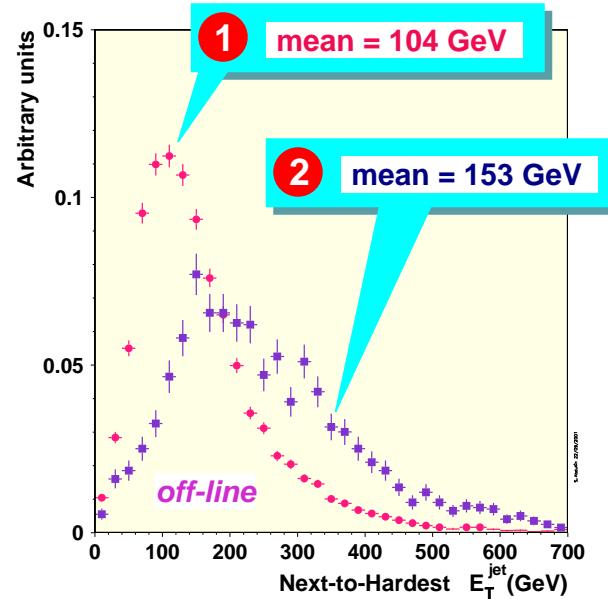
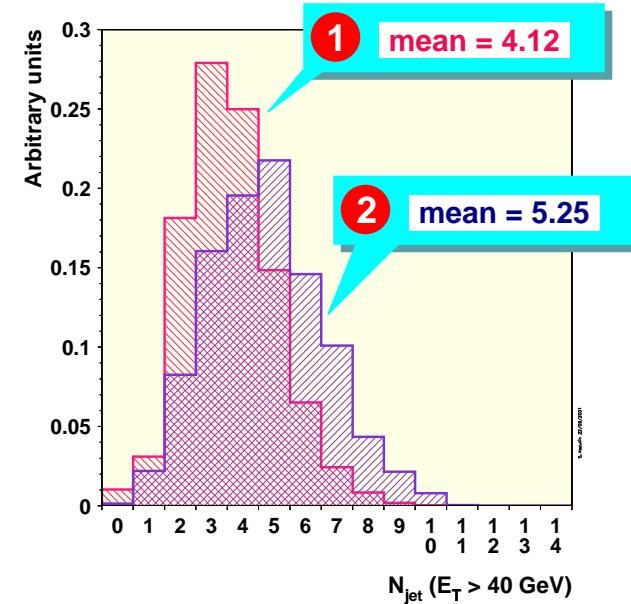
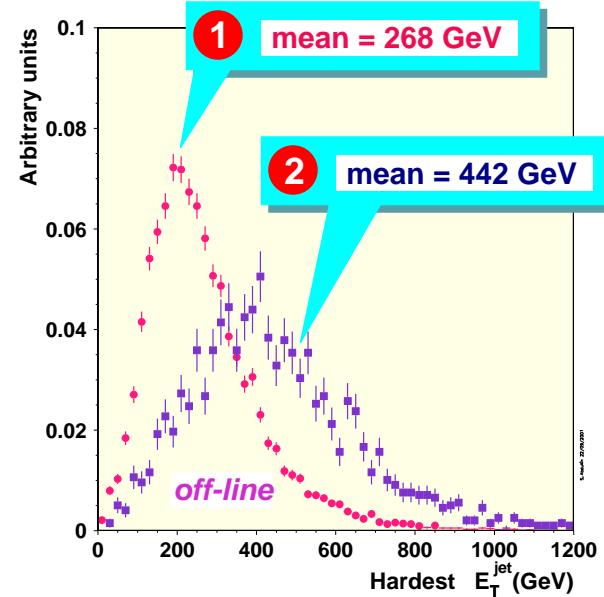
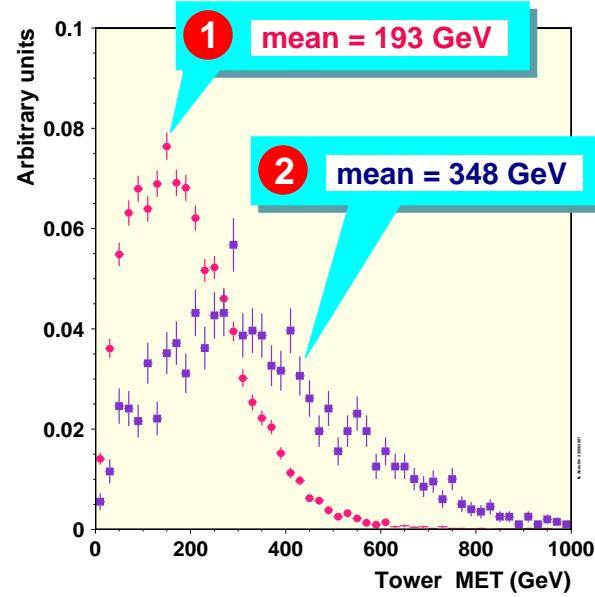
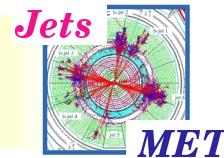
■ Even 0.1 fb^{-1} would require

- $Wj \sim 160,000$ events } $\hat{p}_T > 100 \text{ GeV}$
- $Zj \sim 60,000$ events }
- $t\bar{t} \sim 80,000$ events +
 $\sim 30,000$ for single top
- $\text{QCD} \sim 7 * 10^6$ events } $\hat{p}_T > 200 \text{ GeV}$

■ Physics TDR challenge ?

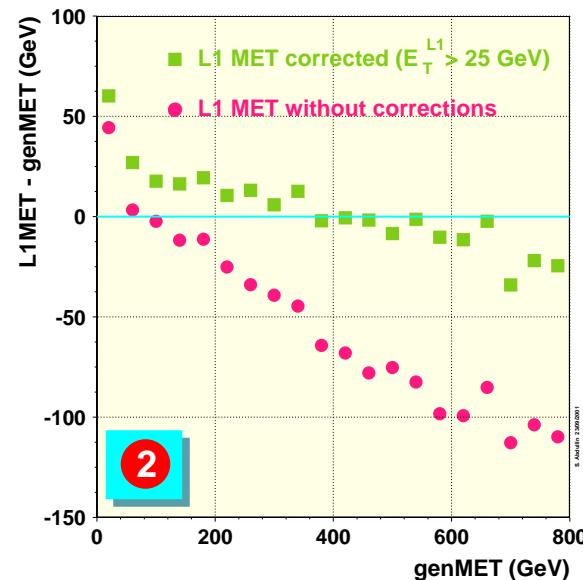
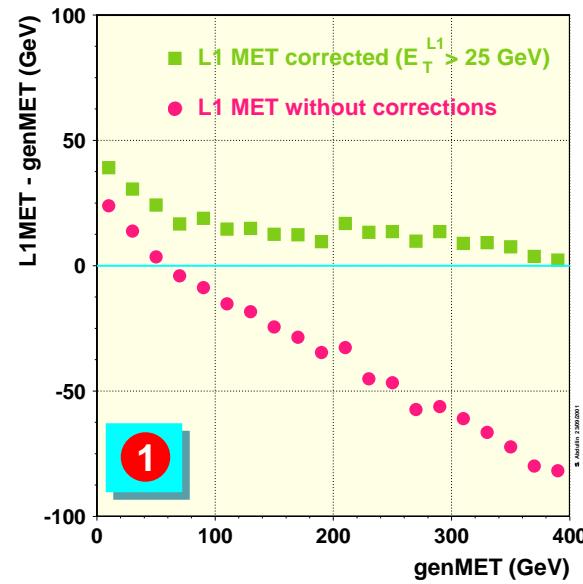
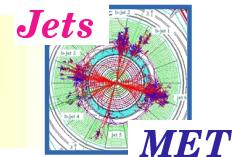


PROBING POINTS DISTRIBUTIONS (I)





JET ENERGY CORRECTIONS APPLIED

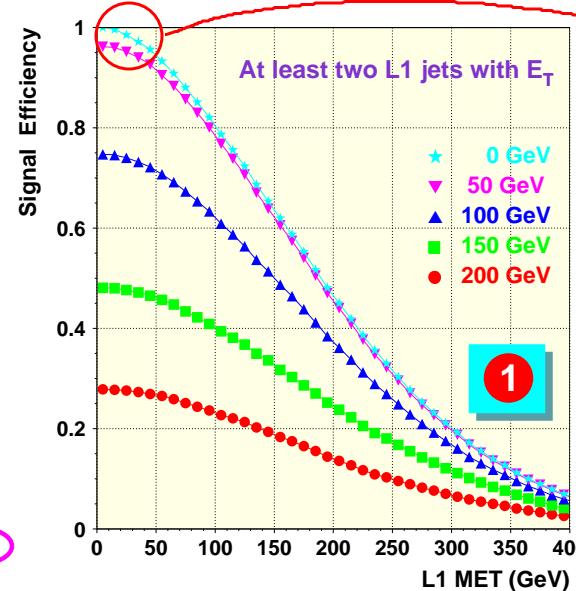
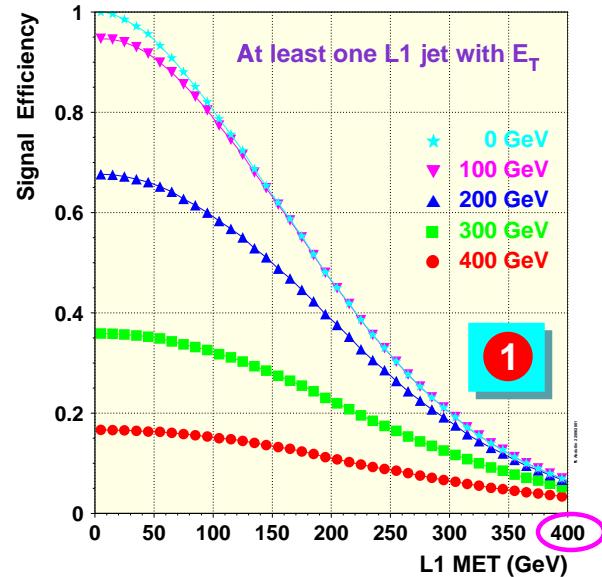
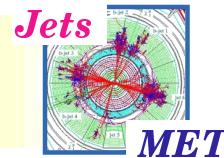


■ Jet corrections

- Andrei Krokhutine's for high luminosity
[http://home.fnal.gov/~sceno/jpg/fall2000jetcorr/...](http://home.fnal.gov/~sceno/jpg/fall2000jetcorr/)
- applied to both L1, L2 objects
- Jets corrected : $E_T > 25$ GeV
- L2 (towers) MET :
corrections on tower E_T x,y-components
in L2 jets are added
- L1 MET :
corrections on L1 jets E_T x,y-components
are added

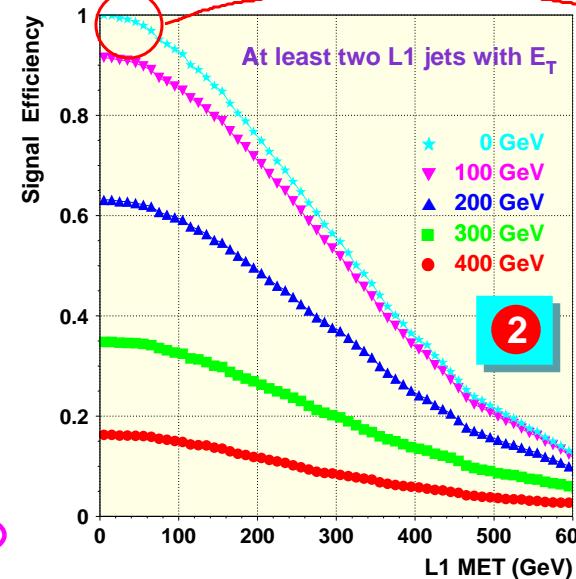
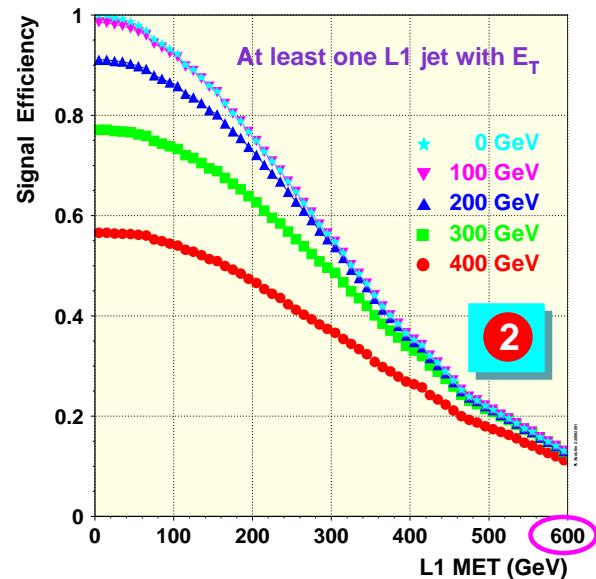


L1 MSUGRA SIGNAL EFFICIENCY



rate $\sim 0.2 \text{ Hz}$ at $2 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$

$2 \times 10^6 \text{ Hz / mb}$

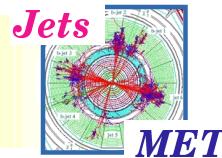


rate $\sim 0.004 \text{ Hz}$

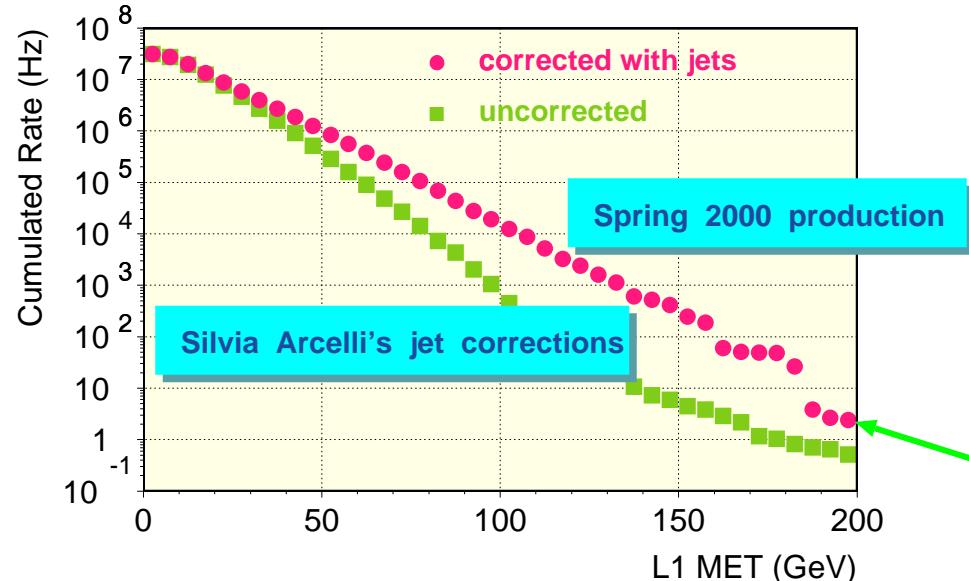
- From fast MC (CMSJET) we know MET is the main mean to disentangle the signal from huge background
- Not the multijet signature alone !



BACKGROUND

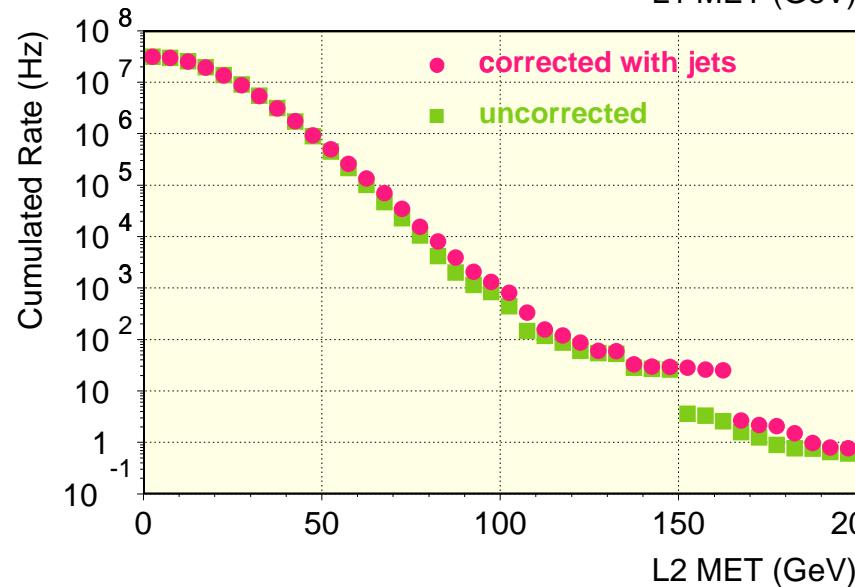


QCD MET Rates at High Luminosity (weighted bins)



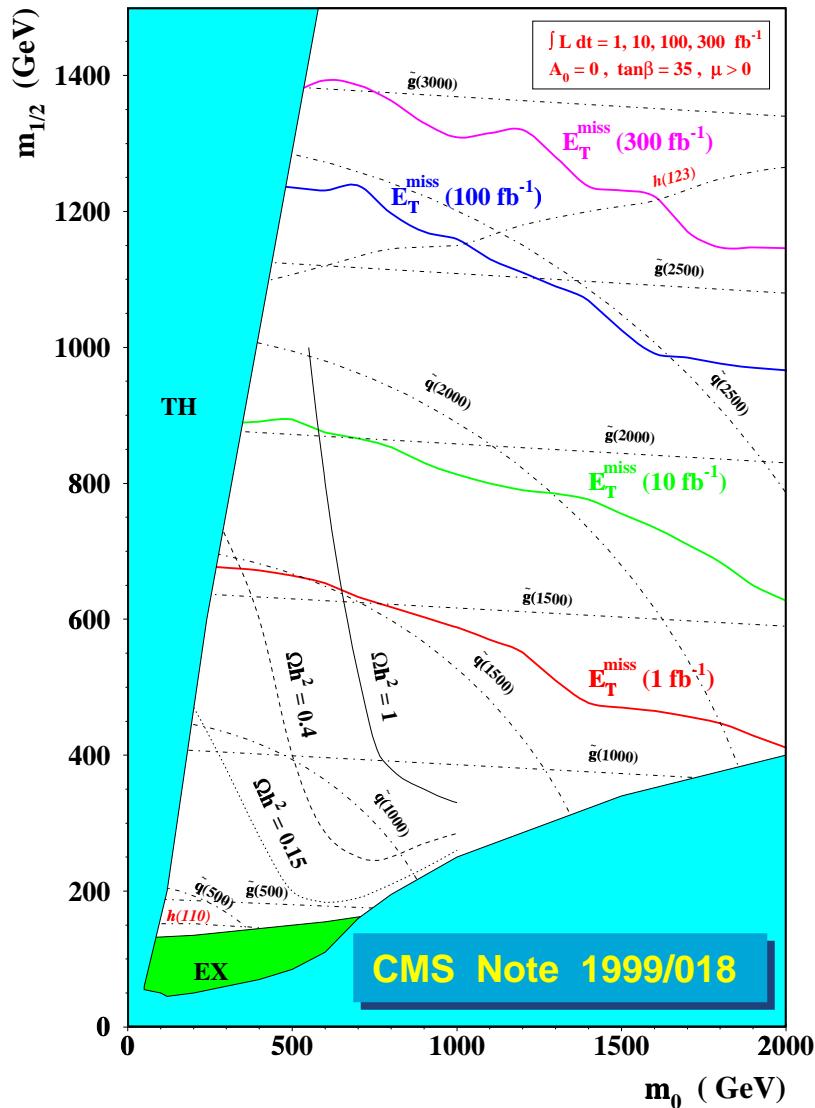
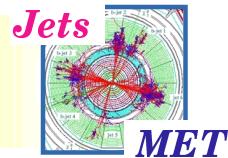
At low luminosity

- <17.3> min. bias events per bunch crossing → <3.5>
- expected < 0.5 Hz for QCD background at L1 MET = 200 GeV
- expected < ? Hz for QCD background at L1 MET = 300-400 GeV

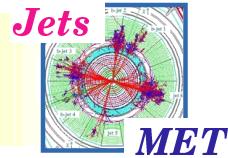




CONCLUSIONS (SUSY TRIGGER AT LOW LUMI)



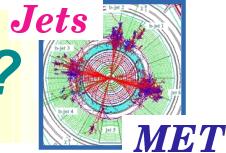
- Even though everybody knows SUSY is so easy to discover via excess of multijet + missing E_T events versus SM expectations ...
- Even though our simple estimates show it's likely so ...
- It's worth getting more precise bkgd estimates at high MET (main handle of bkgd suppression !)
 - more high- p_T QCD samples
 - top (single/double) production
 - W/Z + jets at high- p_T
- $M_{\text{SUSY}} \sim 2 \text{ TeV}$ is probably reachable already at low lumi ?



- What we are worrying about ?
- Data samples
- Di-jet results
- Z' results



WHAT'S THE PROBLEM WITH ECAL THRESHOLDS ?

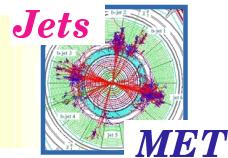


- ECAL selective readout assumes a significant reduction (factor ~ 20) of full data (10 frames) samples stored for the subsequent off-line analysis
 - Zero suppression above some cut (2.5σ ?) out of "interesting" regions
 - All (or almost) preserved in specified (ECAL L1) "interesting" regions
- What about jet (di-jet) energy resolution and missing E_T measurement precision ?
- ECAL community : it's OK, not a main limiting factor ...

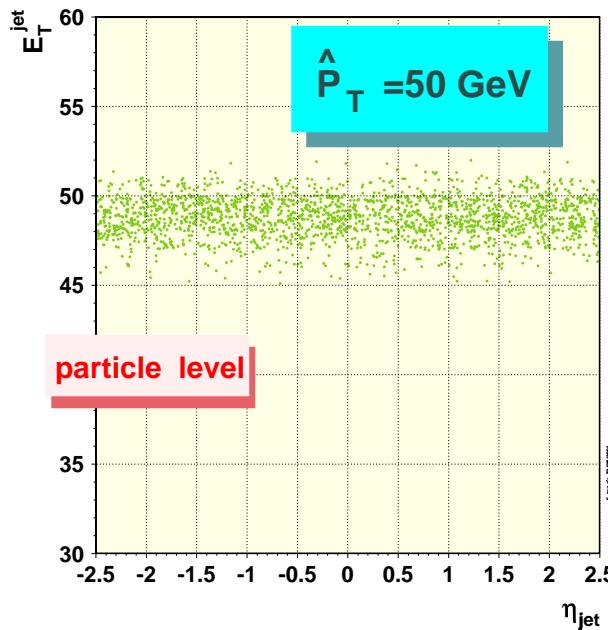




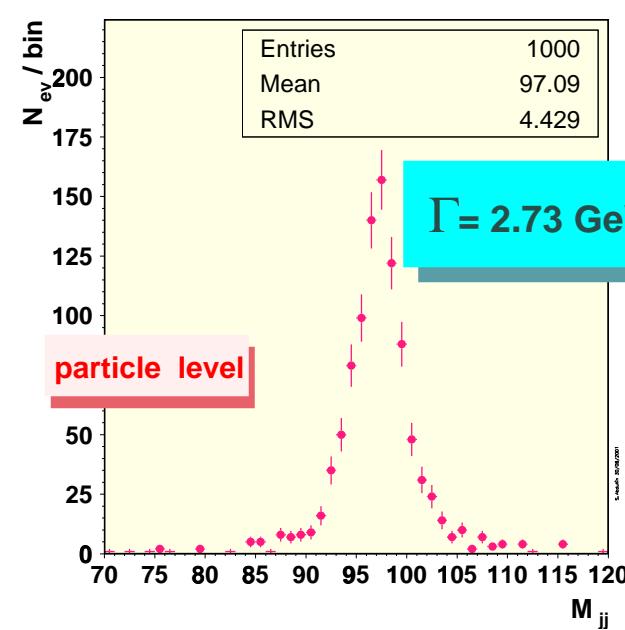
SAMPLES



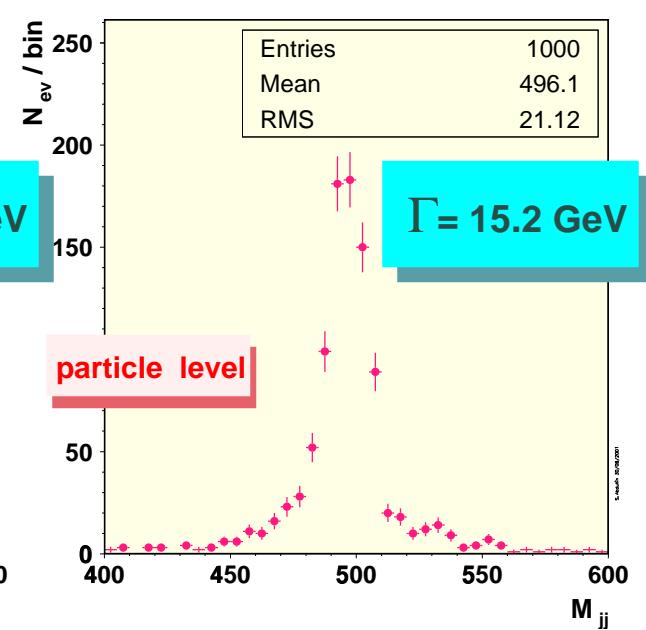
● QCD di-jet (u,d)



● $Z' (100) \rightarrow jj$ (u \bar{u} , d \bar{d})



● $Z' (500) \rightarrow jj$ (u \bar{u} , d \bar{d})

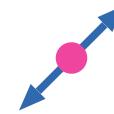


● ISR / FSR
multiple interaction } off

● Particle-level preselection :
min. 2 jets with $E_T > 30 \text{ GeV}$
within $\eta < 2.5$

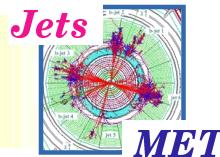
● underlying event - off
 Z' decays at rest

● Particle-level preselection :
min. 2 jets with $E_T > 30 \text{ GeV}$
within $\eta < 2.5$





CALCULATIONAL DETAILS



■ Readout thresholds

Set No	HCAL threshold (MeV)	ECAL threshold (MeV) barrel / forward		Comment
1	300	60 **	300 **	Old HCAL default cuts
2	500	100	500	New HCAL
3	300	60 **	300 **	idem
4	300	30 *	150 *	idem
5	300	0	0	idem
6	300	- ∞	- ∞	idem

** $2\sigma_{\text{noise}}$

* $1\sigma_{\text{noise}}$

■ IterativeCone Jetfinder

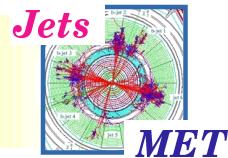
- $R = 0.5$
- Seed = 3 GeV
- $\min E_T = 30 \text{ GeV}$

Default ORCA implementation

- 1 depth layer (HB/HE) + HO
- Layers 1 & 2 "re-weighted"
- Signal integration in 2 bkts
- ADC quantization
- Photo statistics effect
- Hit time jitter
- HF splitted from HB/HE



BACK-OF-ENVELOPE ESTIMATES



"It's so simple, it might even work!"

Dan Green (?)

- ECAL : 2500 Xtals in R=0.5, $\sigma = 30$ MeV in EB

- HCAL : 100 towers,

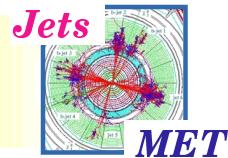
$$\sigma = 200 \text{ MeV} * \sqrt{2 \text{ readouts} * 2 \text{ layers}} \sim 400 \text{ MeV}$$

+ HO !

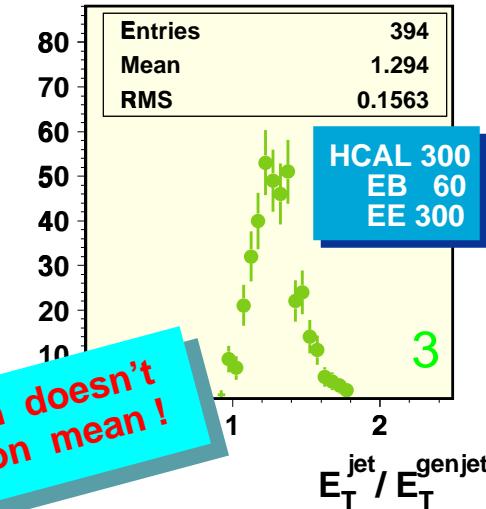
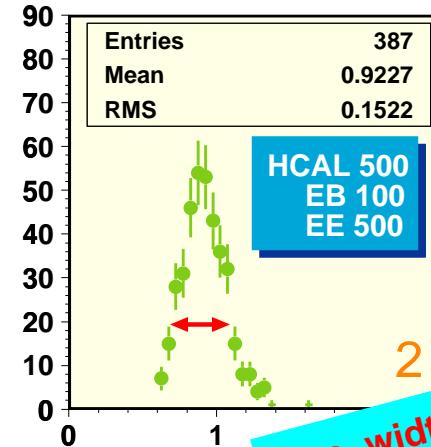
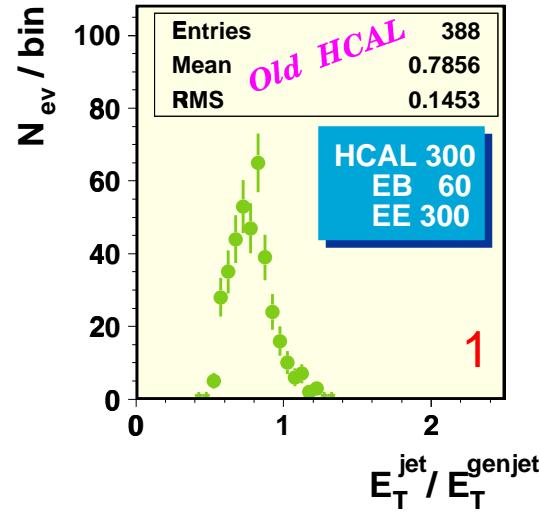
cut (σ)	fraction	mean (σ)	jet content (GeV)	
ECAL HCAL				
0	0.5	0.8	30.0	16.0
1	0.15850	1.524	18.3	9.7
2	0.02875	2.372	5.0	2.7
3	0.00135	3.276	0.3	0.2



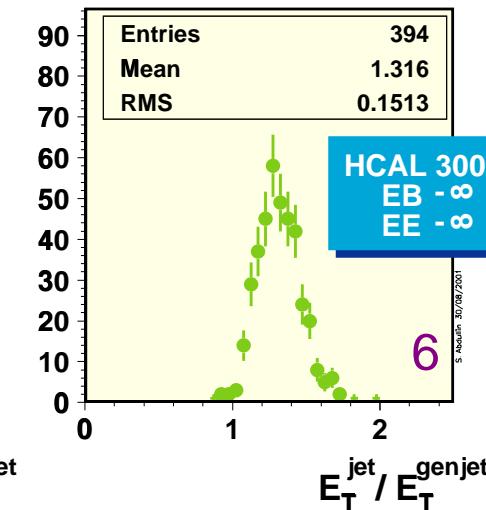
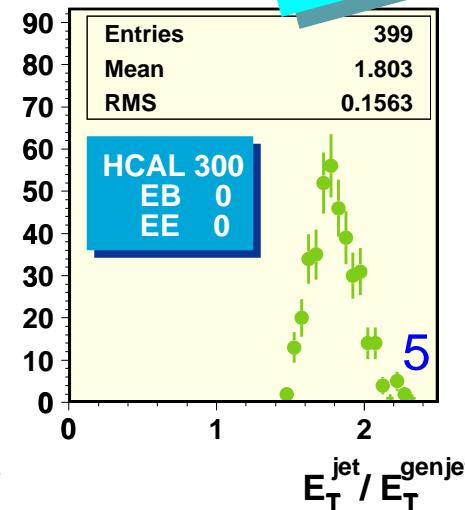
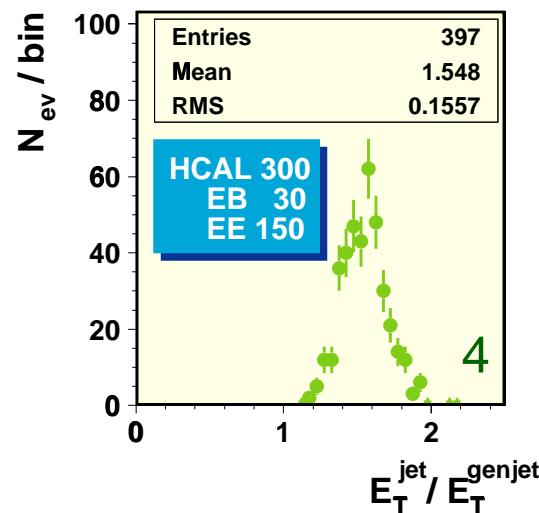
DI-JET RESULTS (I)



● $|\eta| < 0.5$

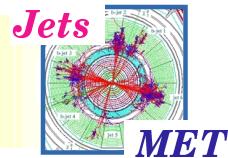


The width doesn't depend on mean!

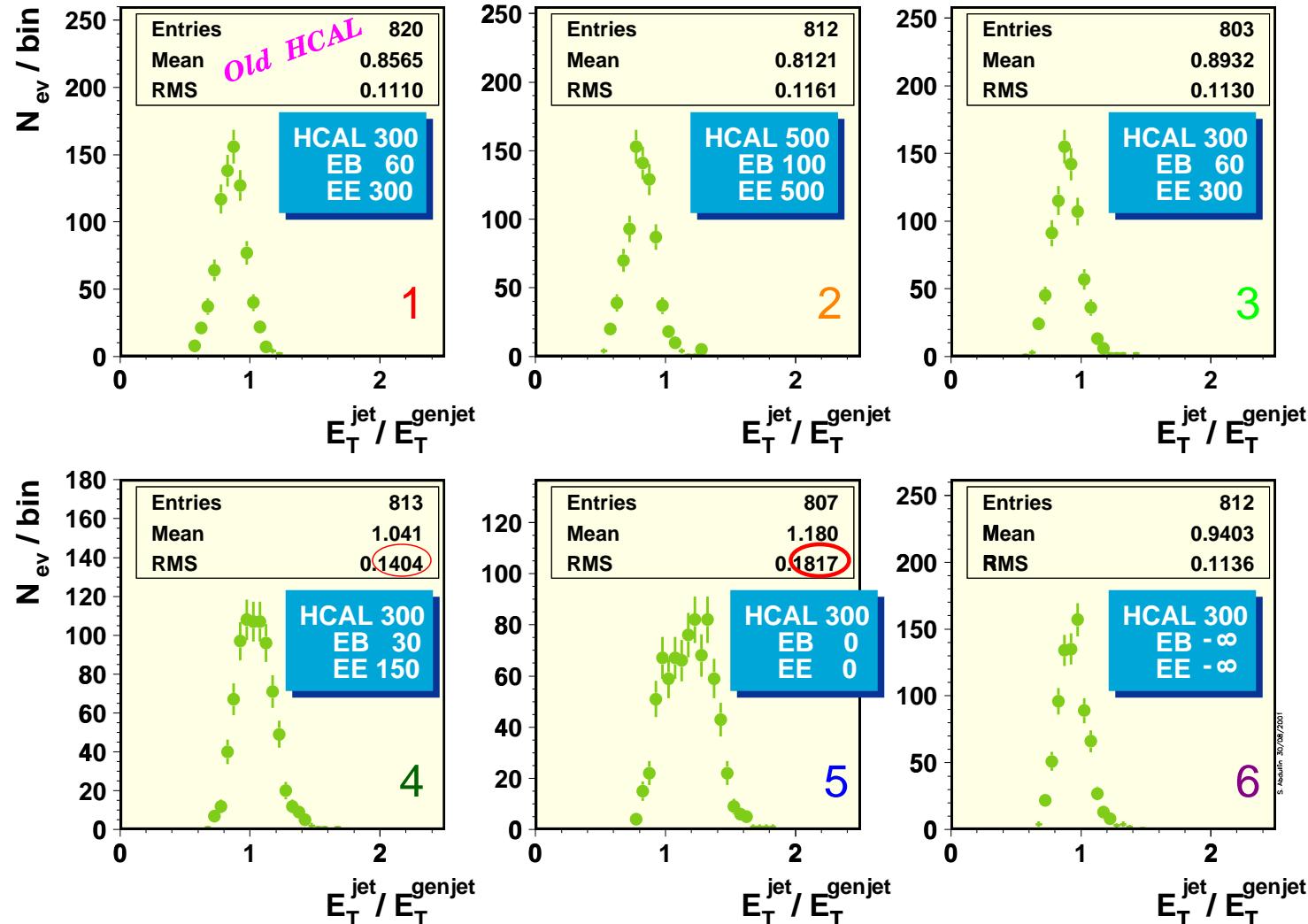




DI-JET RESULTS (II)

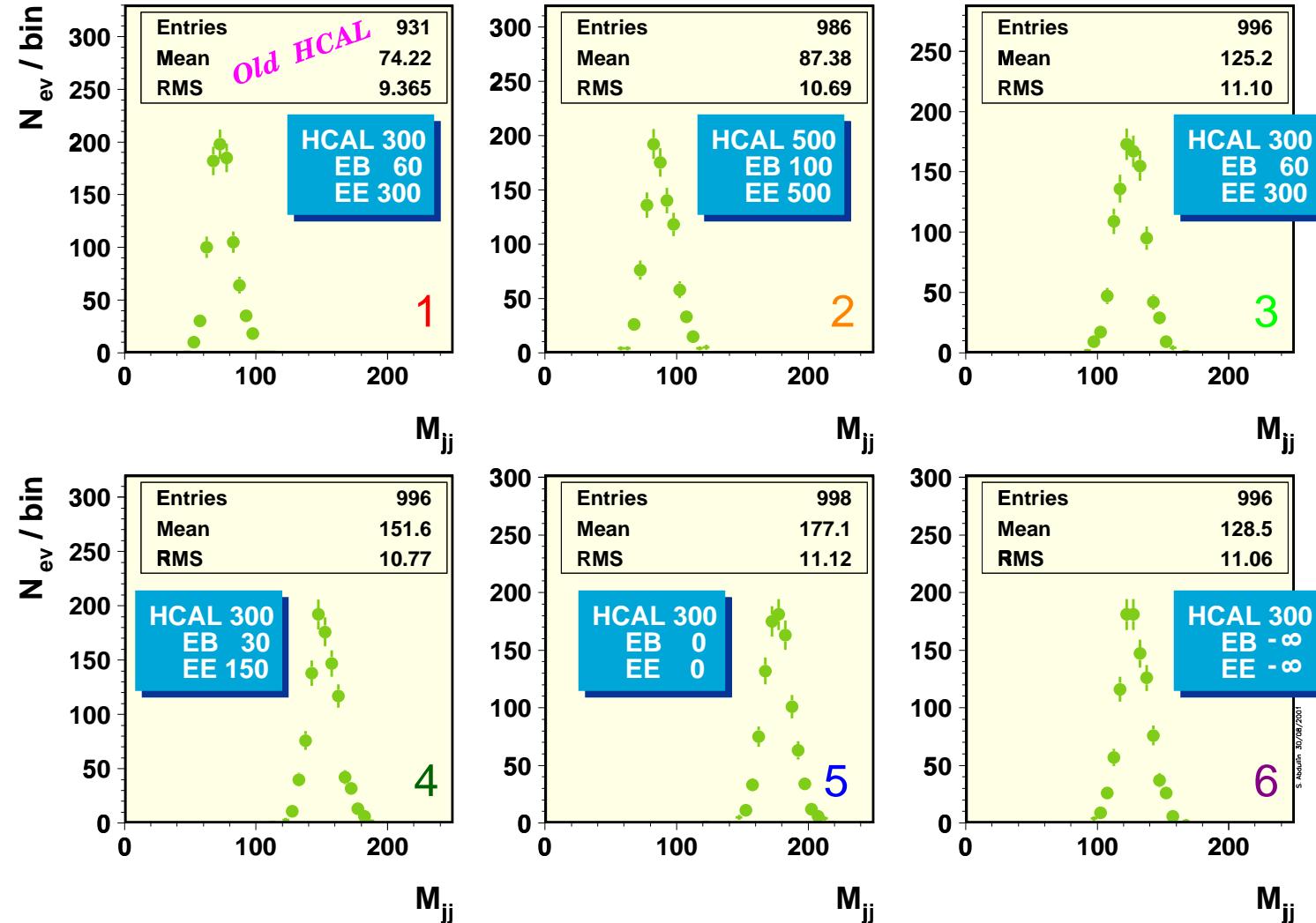
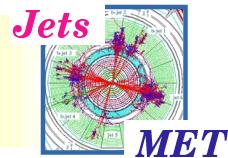


● $|\eta| > 1.5$



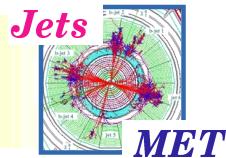


$Z'(100) \rightarrow jj$ RESULTS (I)

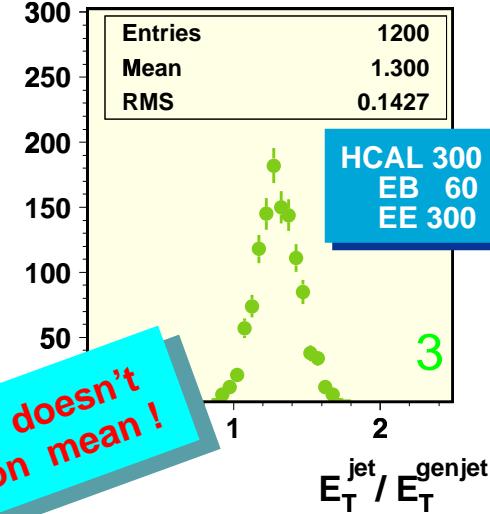
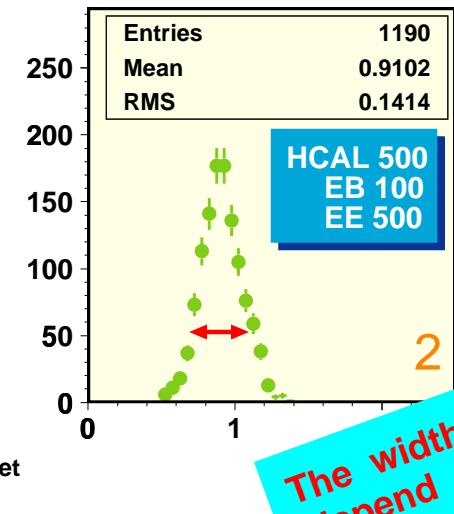
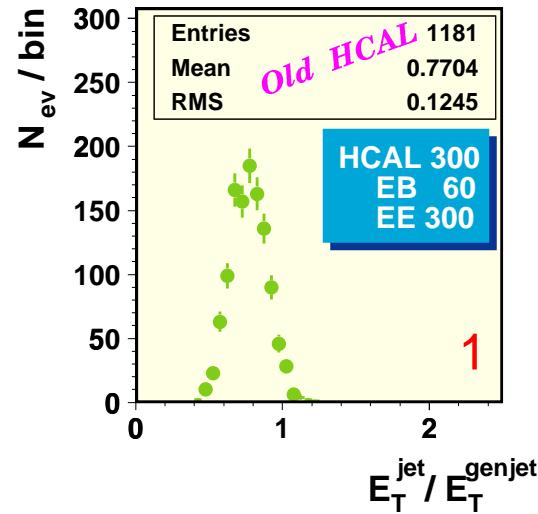




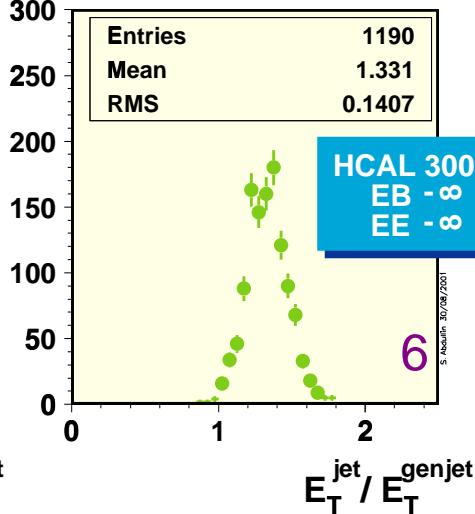
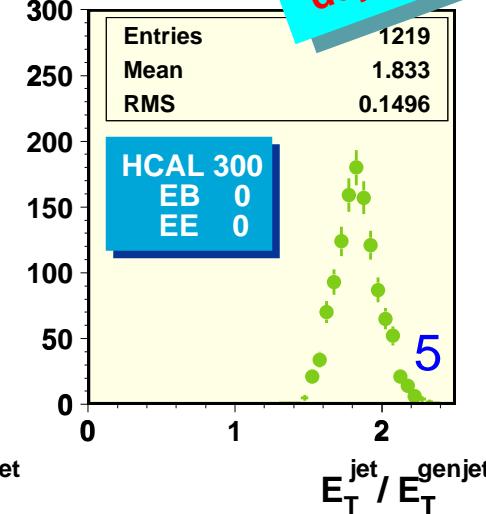
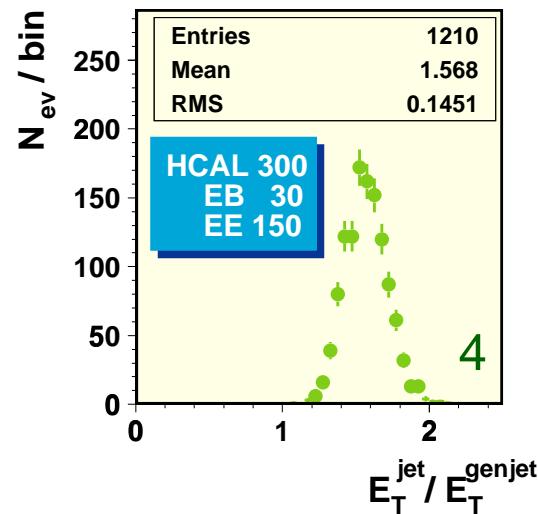
$Z'(100) \rightarrow jj$ RESULTS (II)



● $|\eta| < 0.5$

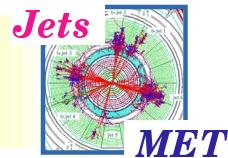


The width doesn't depend on mean!

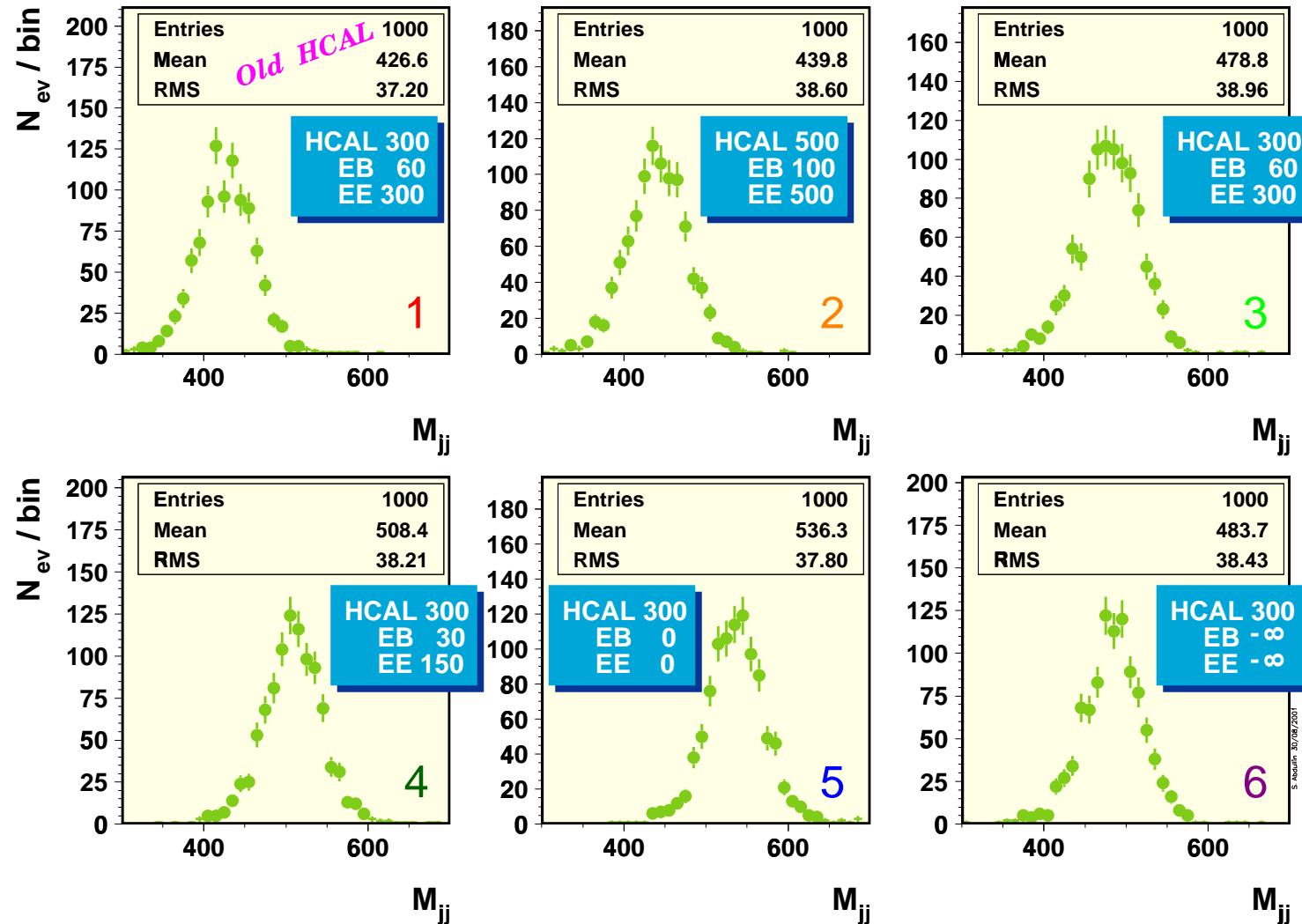




$Z'(500) \rightarrow jj$ RESULTS (I)

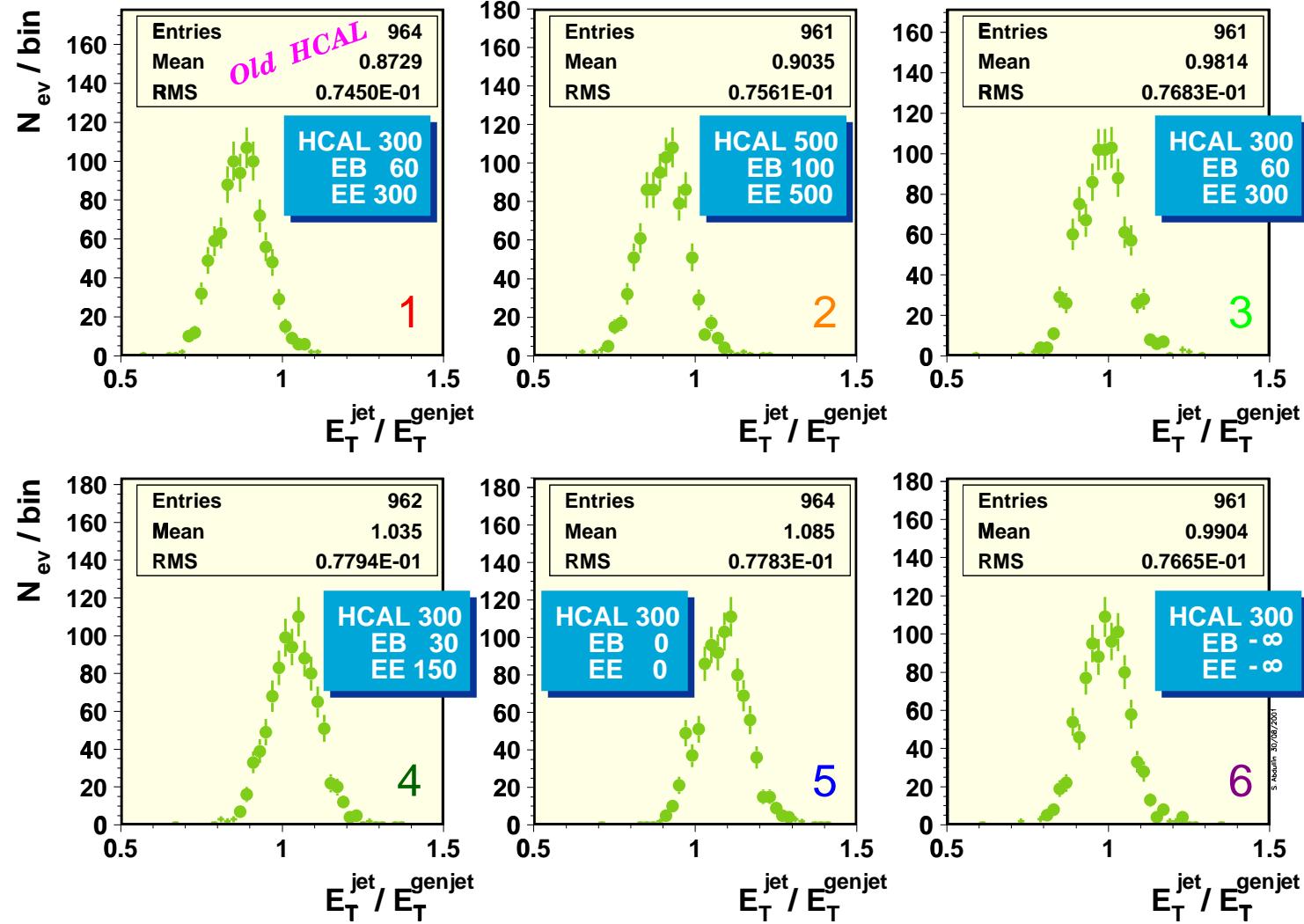
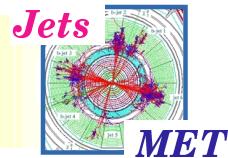


Similar to $Z(100)$



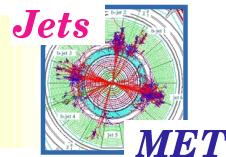


$Z'(500) \rightarrow jj$ RESULTS (II)





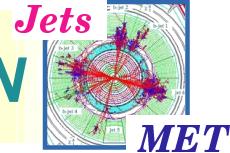
JET / DI-JET SUMMARY



- Generally the widths of jet/di-jet distributions (w/o corrections) seem to be fairly independent on the thresholds
 - a kind of trade-off (?) :
 - higher threshold -> less noise -> better resolution, but ...
 - higher threshold -> less jet constituents -> worse resolution
- Each set of thresholds require it's own jet energy corrections to see how eventually the resolution changes
- To be continued ...
 - more statistics



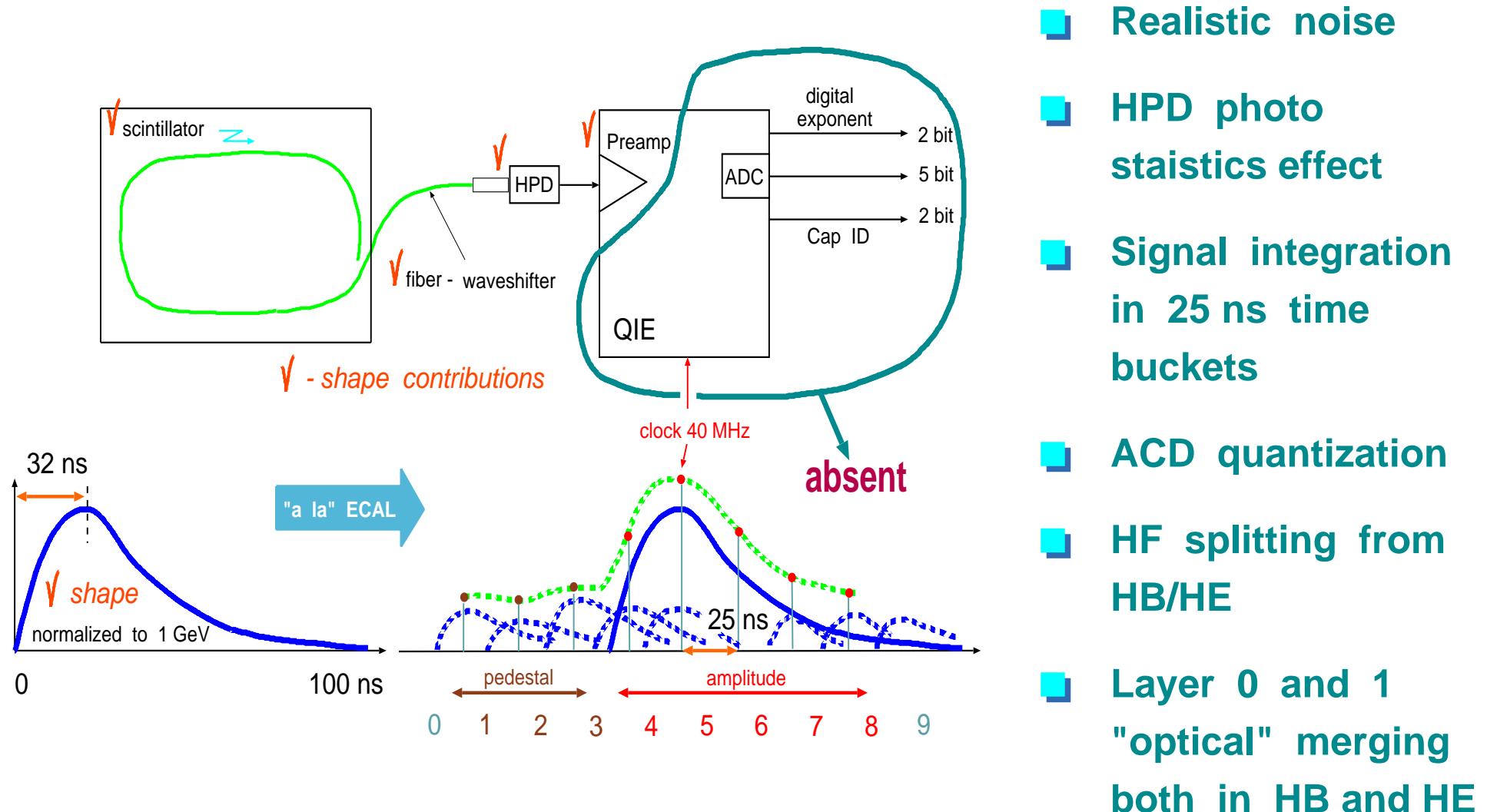
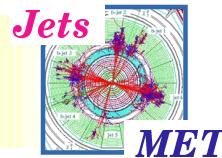
UPDATE ON FRONT-END ELECTRONICS SIMULATION



- Last report at HCAL week (June 15, 2001)
 - <http://cmsdoc.cern.ch/~abdullin/jetmet/meetings/15jun01/talk.pdf>
[update.pdf](http://cmsdoc.cern.ch/~abdullin/jetmet/meetings/15jun01/update.pdf)
- General HCAL code update issues
- Updates on HCAL code in ORCA
- "Straightforward" implemetation problems -> toy MC
- Signal shape : short vs long
- Pure noise consideration
- Signal resolution without pileup
- Shape filter(s)
- Noise + pileup
- Summary
 - http://cmsdoc.cern.ch/~abdullin/jetmet/notes/note_3/in01_037.pdf

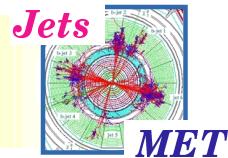


HCAL CODE IN ORCA (UPDATE LIST)





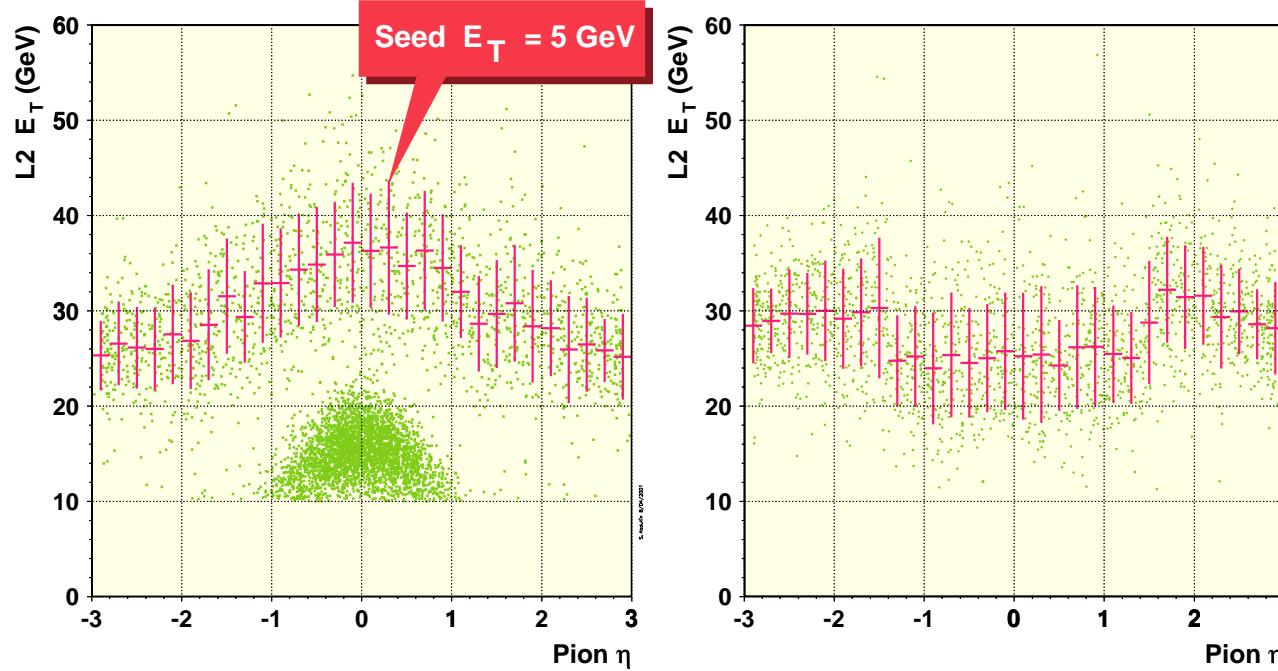
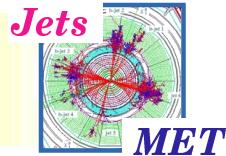
ORCA CODE (CALO PACKAGES) CHANGES



- **HcalRealistic** HF splitted from HB/HE, noise generation, ADC quantization
- **HcalRealisticRec** signal evaluation (off-line)
- **HcalTrigPrim** signal evaluation (L1 trigger)
- **HcalBarrel** layer 0 and 1 merging with weighting ("optical")
- **CaloHit** minor change to enable GEANT hits weighting
- **CaloTrigRec** minor change to split HCAL trigger reconstruction from ECAL one (!)
- **CaloReadout** HCAL ReadOut treatment is separated from ECAL one (so different !)
some optional changes (e.g. map -> static vector of CaloTimeSample)
- **CaloRecHit** some optional changes not related directly to HCAL
- **CaloDetector** some optional changes not related directly to HCAL
(e.g. assigns a unique ordinal number to all calo cells for direct ref.)



ORCA IMPLEMENTATION PROBLEMS

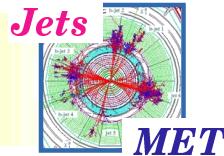


- Calc. details :
 - double pions
 $p_T = 30$ GeV
 - 2 signal + 3 pedestal buckets
 - 2 depth layers
 - IterativeConeAlgorithm with $R = 0.5$ and seed $E_T = 1$ GeV

- In parallel with the code re-writing, there was a need to understand and to optimize the parameters put inside the code
- As ORCA is rather a production tool, not an instrument for the studies of the sort, then ...



THEN, TOY MC ...



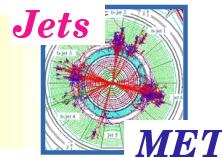
test bed for ORCA

■ Contains almost the same functionality as ORCA does

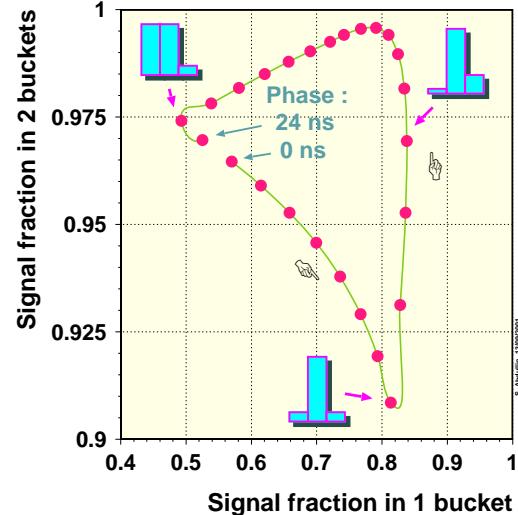
- parameterized and tabulated shape of the signal
- photo statistics effect
- QIE integration
- ADC quantization
- baseline position (typically smeared)
in any of the ADC channels
- variable number of time buckets analogous to ORCA's
CalTimeSample and CaloDataFrame objects
- Gaussian noise (uncorrelated) injection in all time buckets
- various options for the signal collection and pedestal estimates
- adjustable time phase for various collection modes



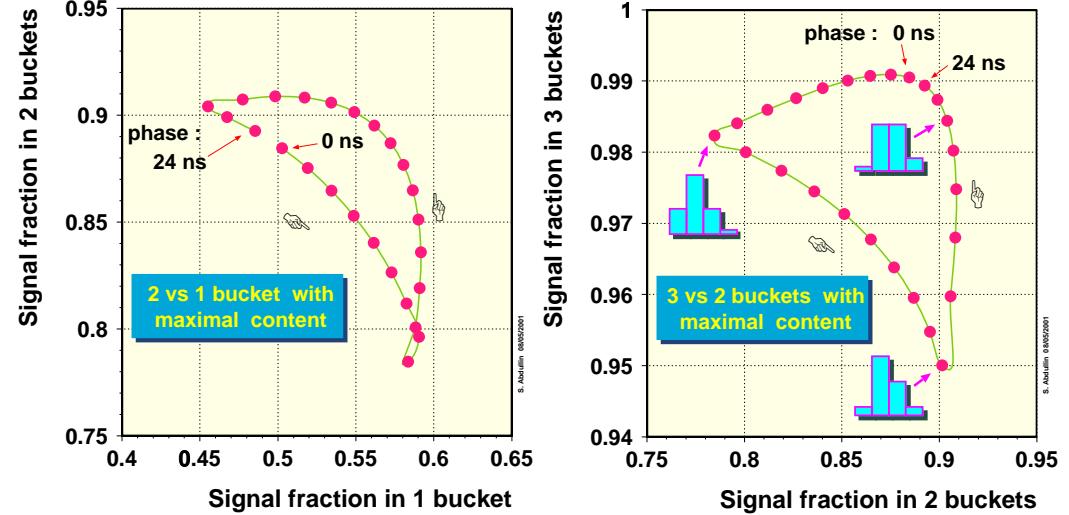
SIGNAL SHAPE



new



old



new

old

● Scintillator + wave-length shifter

$$f_d(t) = \exp(-t/\tau_s), \quad \tau_s = 10 \text{ ns}$$

● HPD

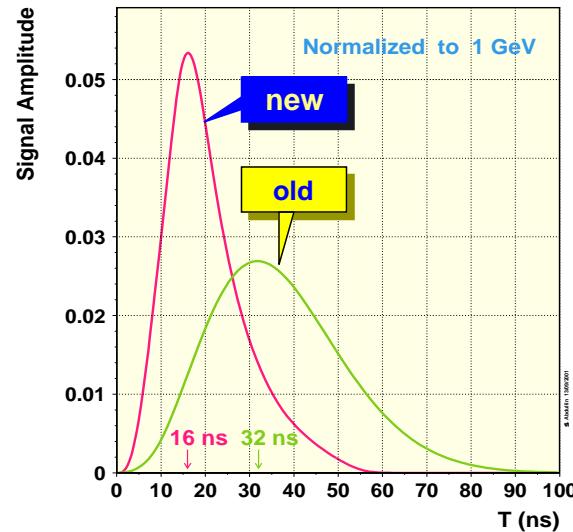
$$f_{HPD}(t) = 1.0 + (t/\tau_{HPD}), \quad \tau_{HPD} = 12 \text{ ns}$$

10 ns

● Preamplifier

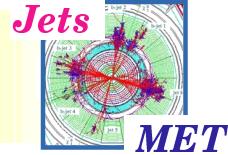
$$f_p(t) = t * \exp(-t/\tau_p), \quad \tau_p = 5 \text{ ns}$$

25 ns





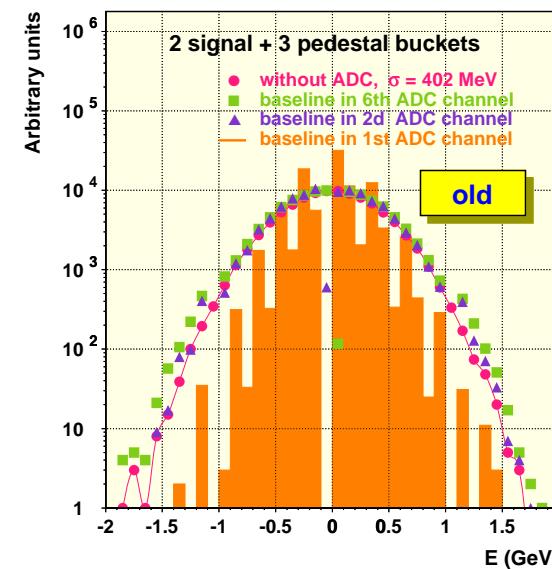
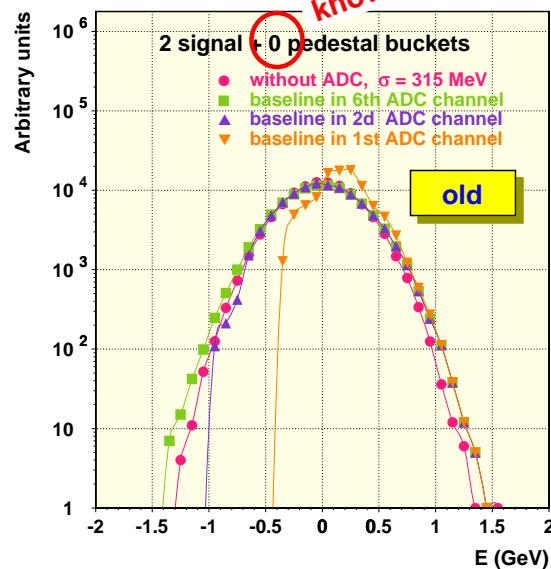
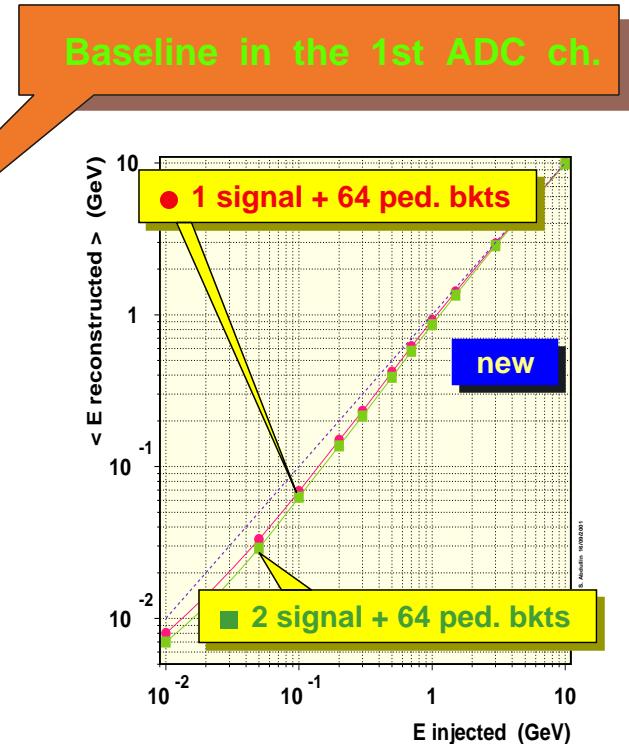
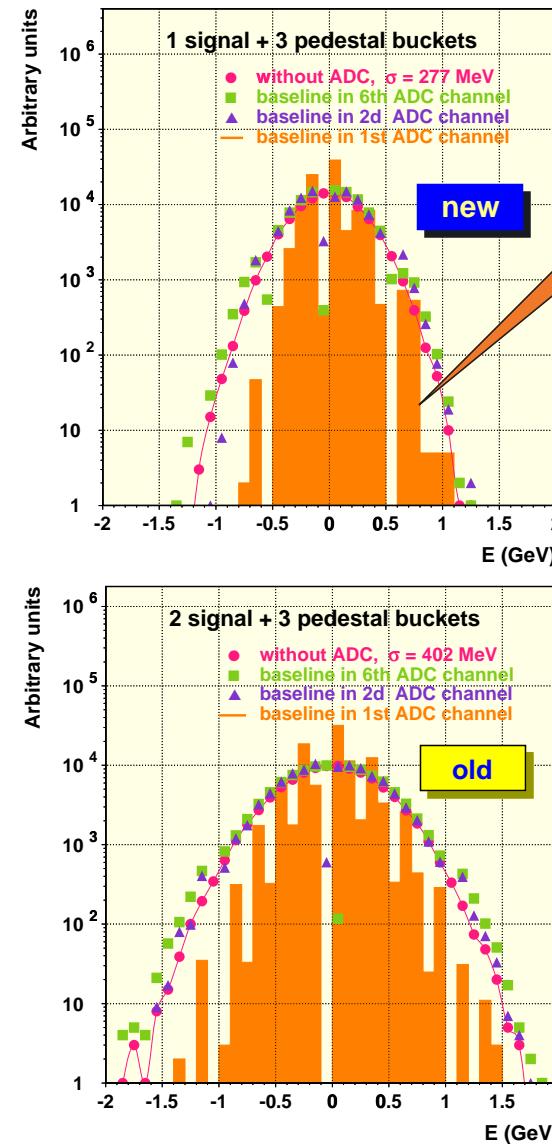
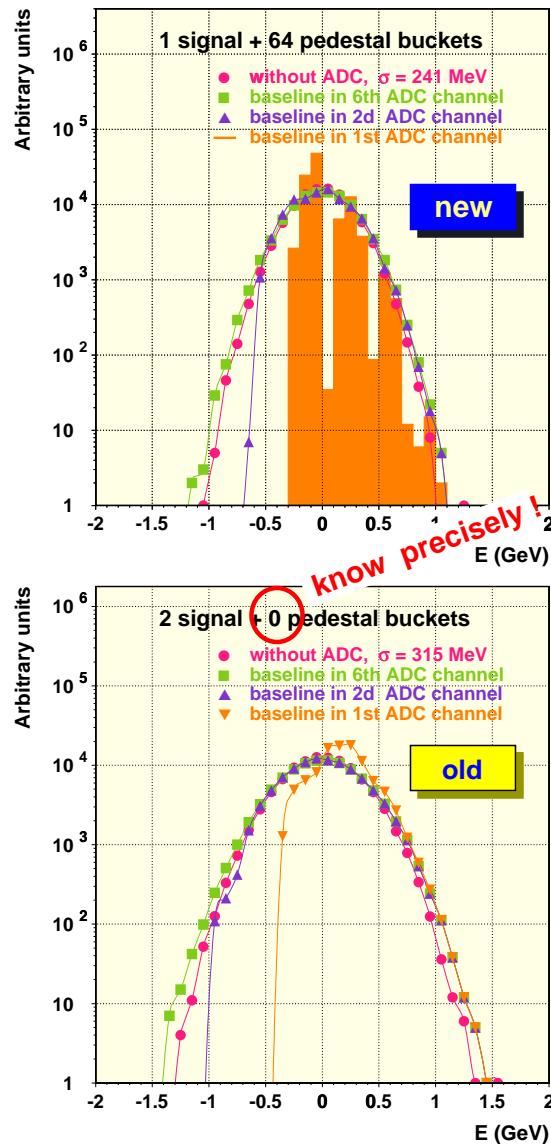
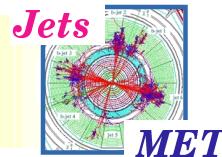
TOY MC : CALCULATIONAL DETAILS



- Gaussian uncorrelated noise $\sigma = 2 \text{ pe} \sim 200 \text{ MeV}$ per time bucket per readout ("fast component")
- Flat random "drift" of the baseline (noise average) within one ADC channel ("slow component")
- Default baseline position - in the 2nd ADC channel
- LSB = minimal size of the ADC channel = $3 \text{ pe} \sim 300 \text{ MeV}$ (at the beginning of the first ADC range)
- 10 pe per GeV is assumed (might be more, closer to HB/HE)
- Pedestal estimate as a running average of 64 sequential digitized time buckets is denoted as "64 pedestal buckets"

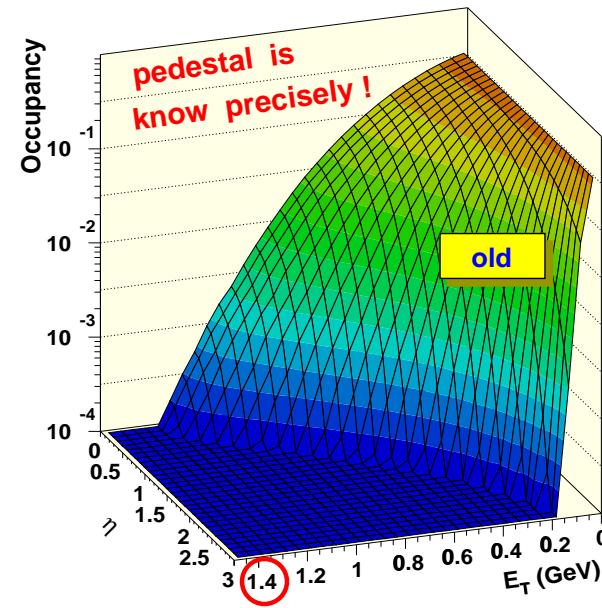
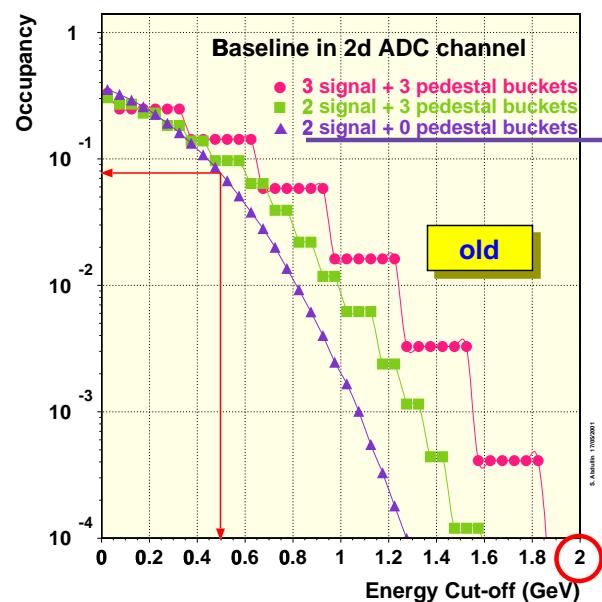
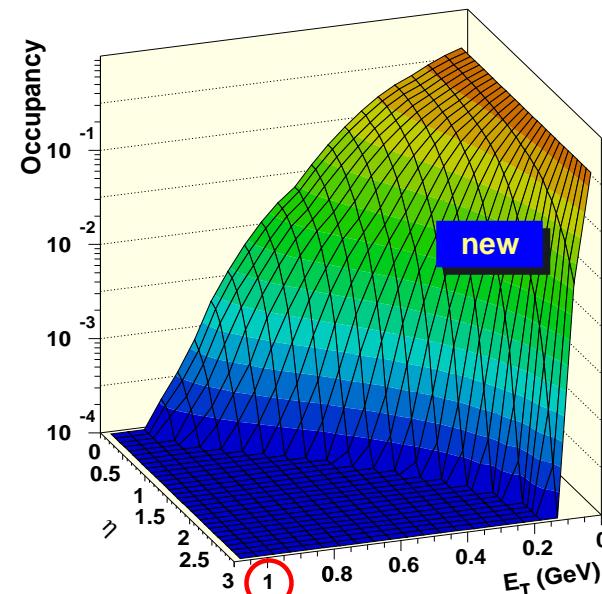
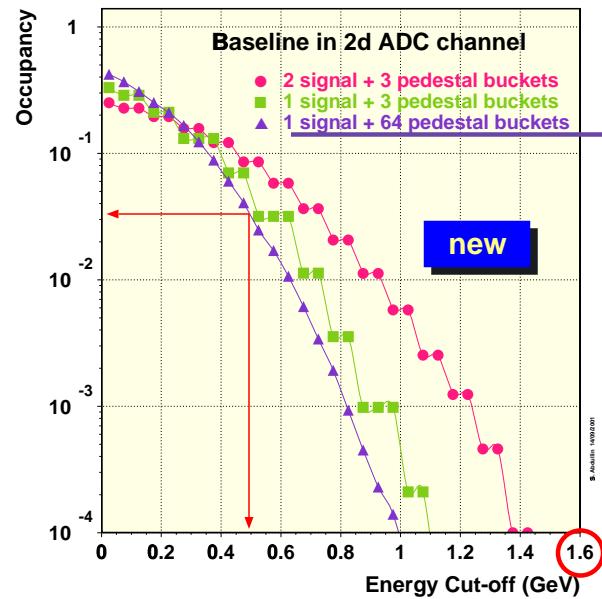
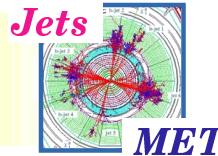


NOISE-INDUCED "SIGNAL" DISTRIBUTIONS



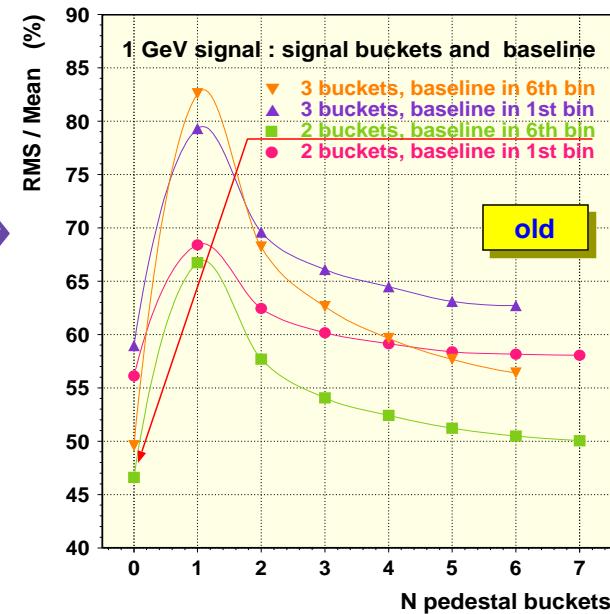
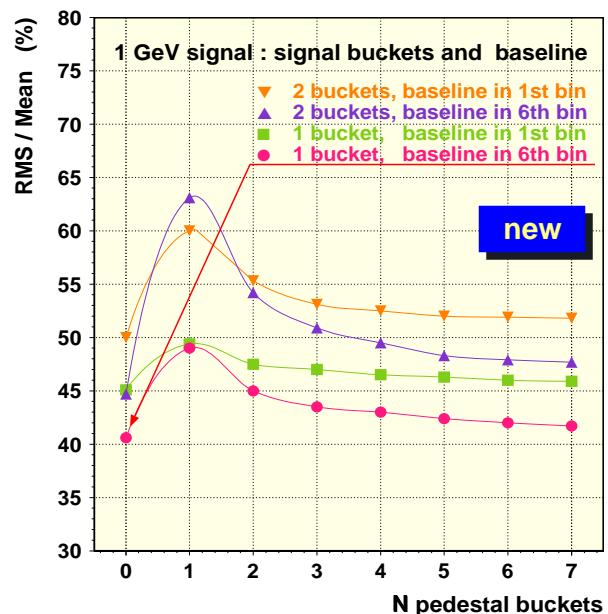
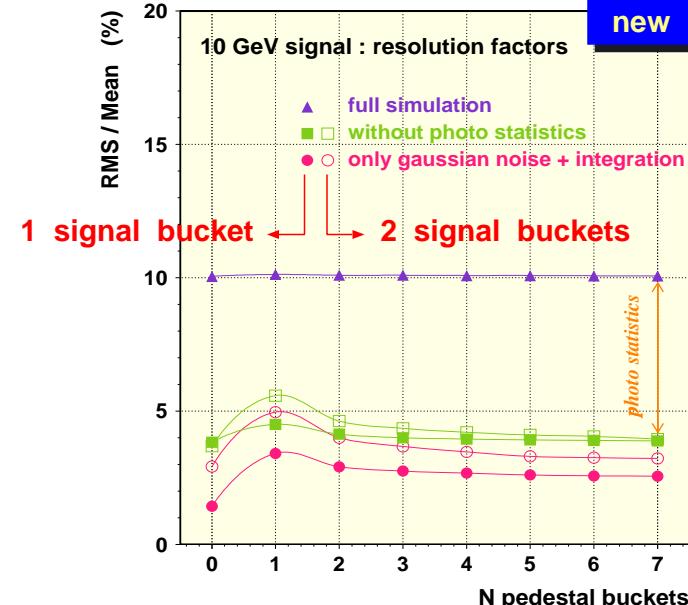
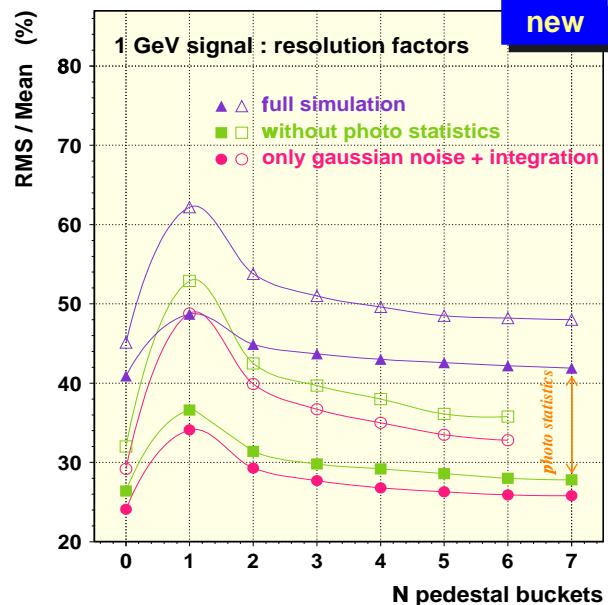
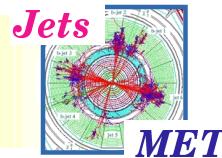


NOISE-INDUCED OCCUPANCY



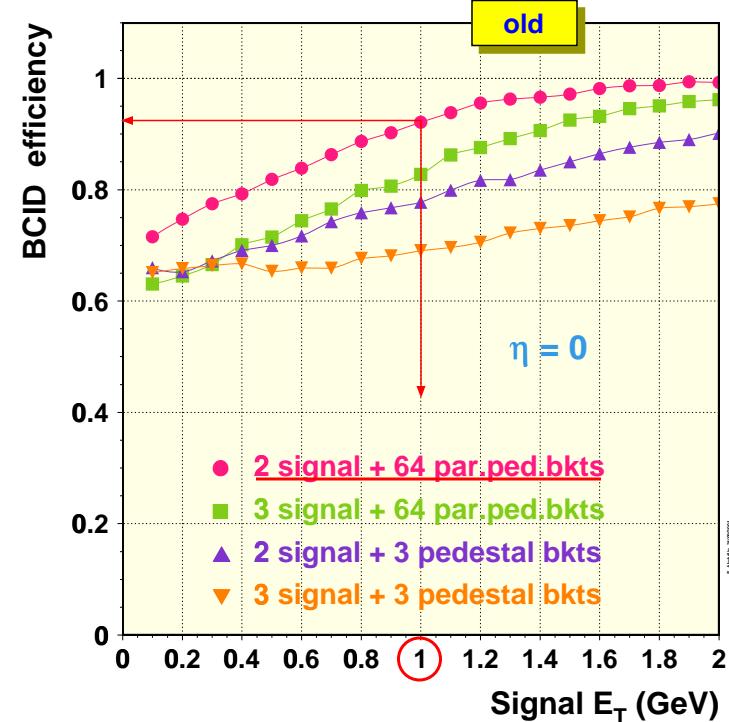
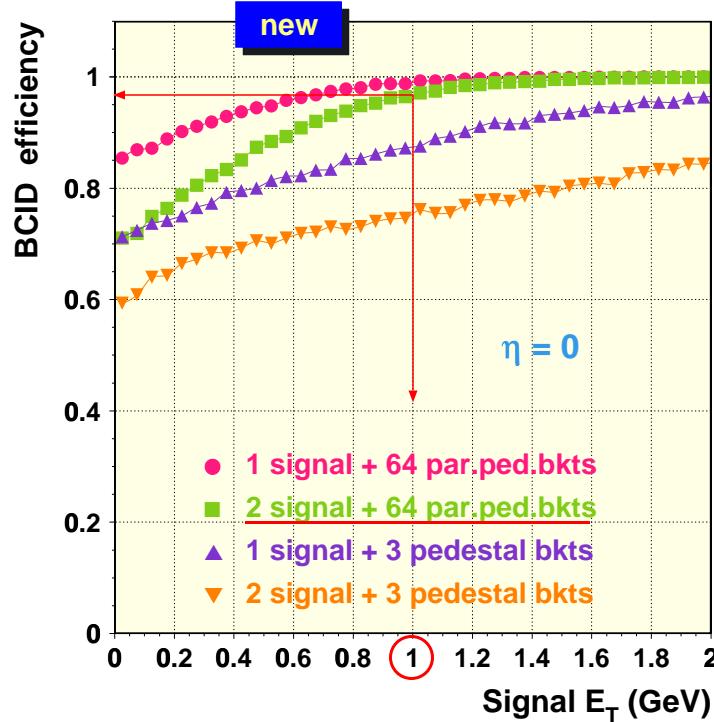
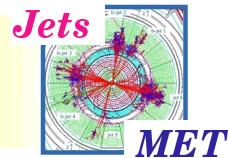


NOISE + SIGNAL





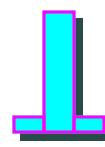
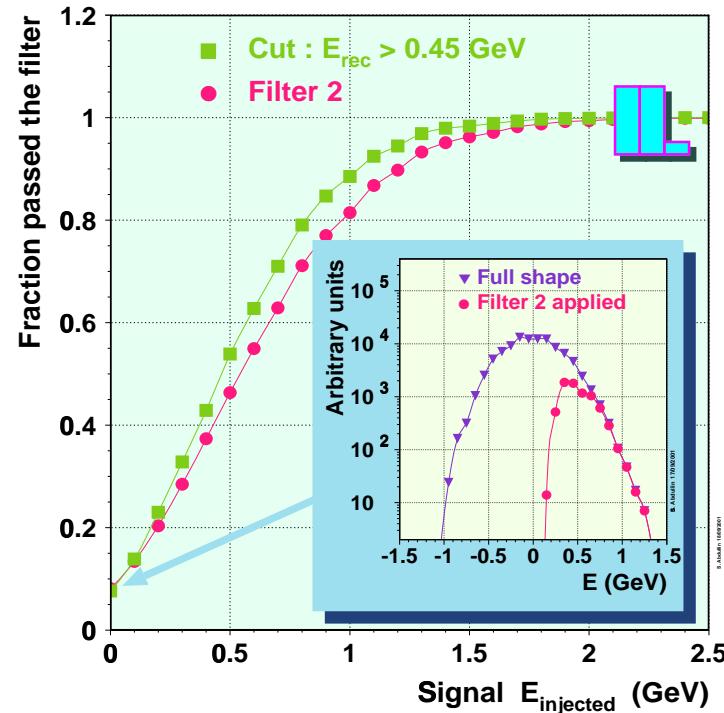
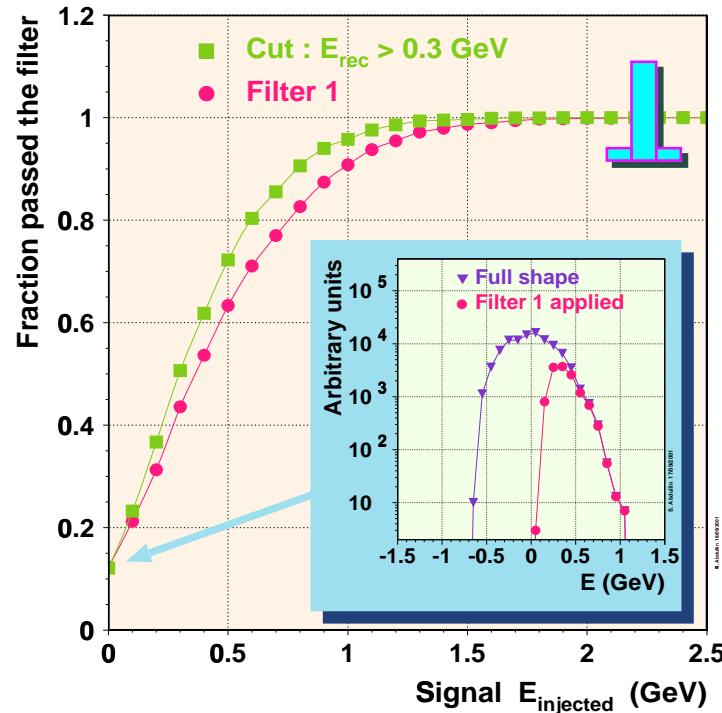
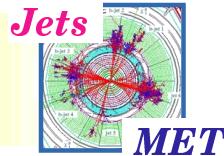
SIGNAL BCID (NOISE ONLY)



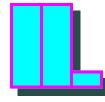
- The signal is evaluated with weights corresponding to the "true time"
- Then - with weights pattern shifted by ± 1 time bucket
- BCID is OK if the signal is maximal (\geq) with zero shift



SHAPE FILTER (FOR NOISE)



- Signal bucket content ≥ 1 ADC count
- $-1/+1$ time bucket content $<$ peak bucket one



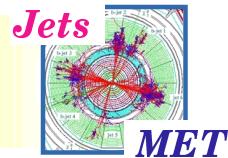
- Both signal buckets content ≥ 1 ADC count
- diff (max, min) ≤ 3 ADC counts



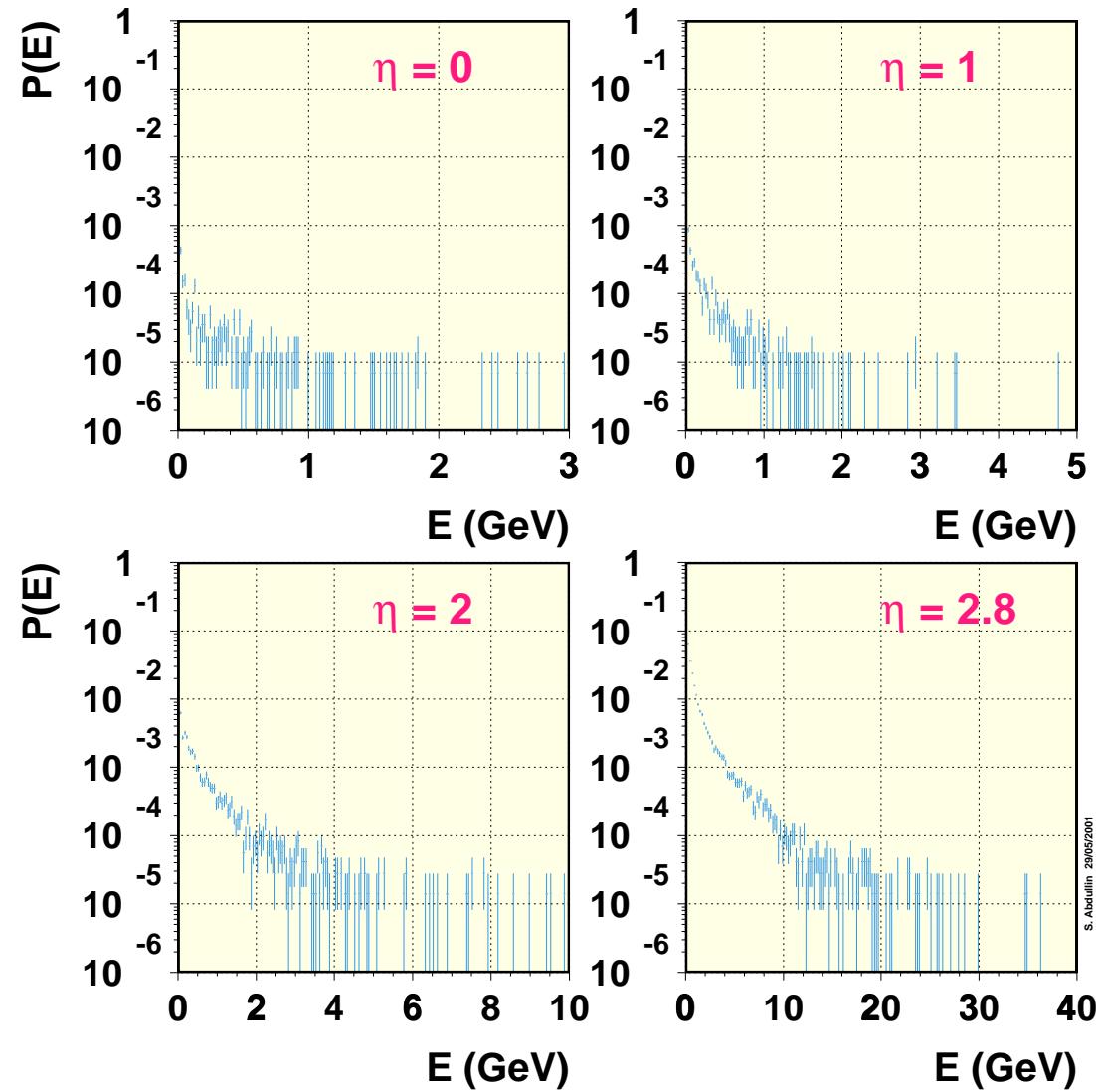
High noise level (+ big LSB) hampers shape-based noise filtering



PILEUP IN TOY MC

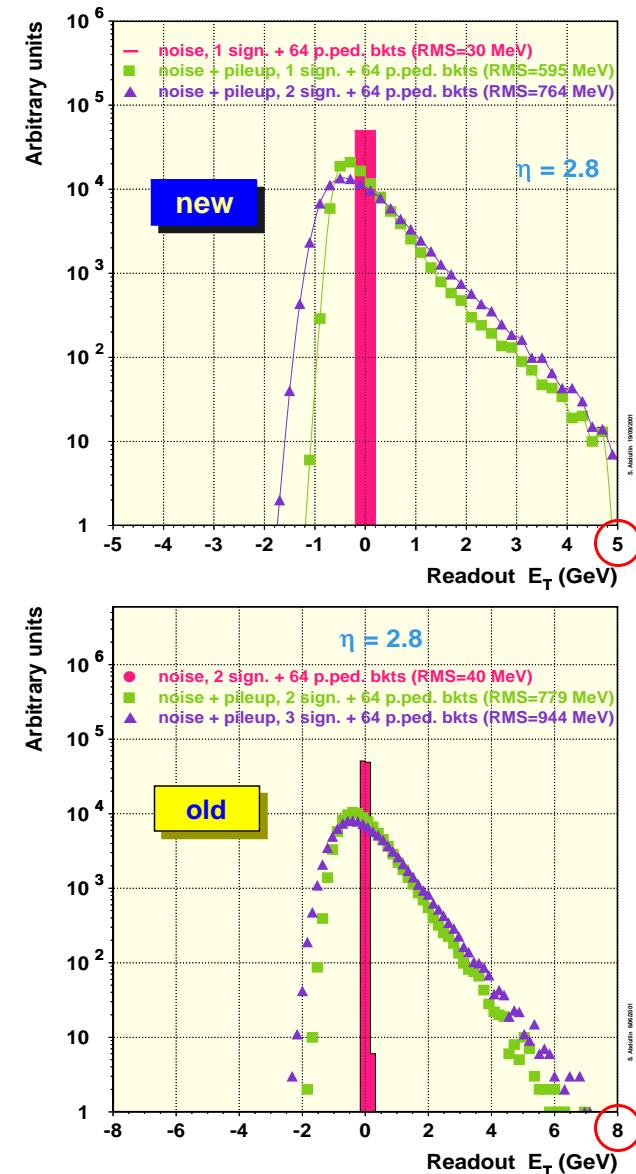
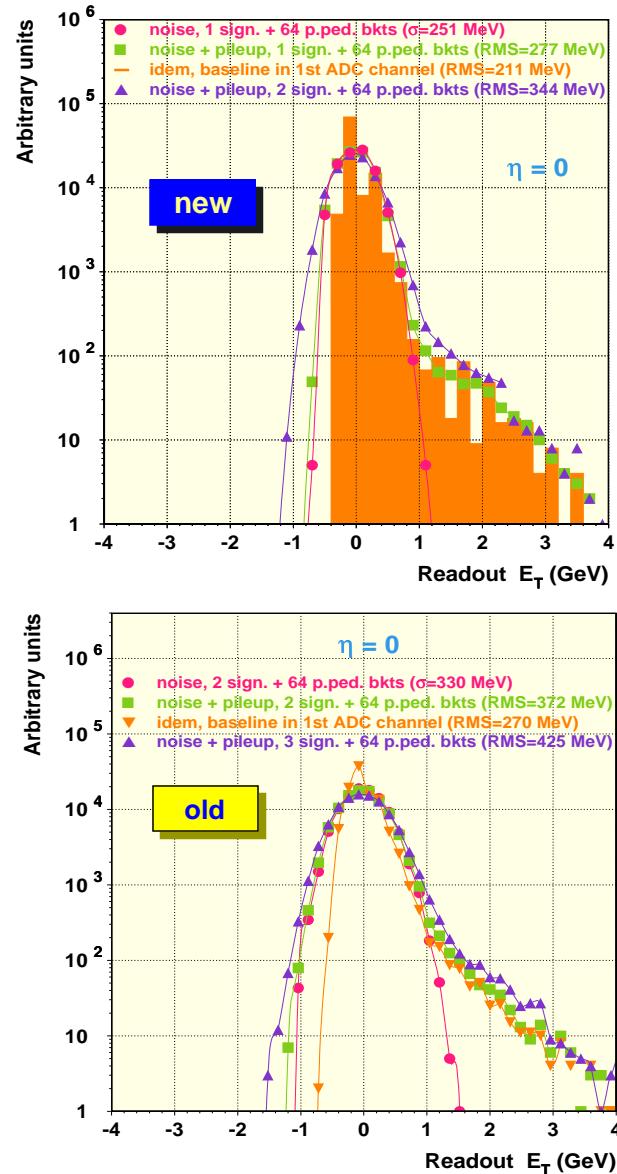
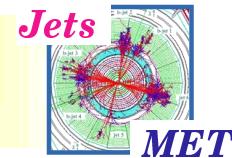


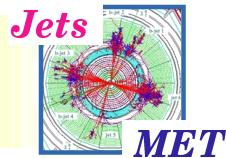
■ Single minimum bias events (ORCA_4_5_1)



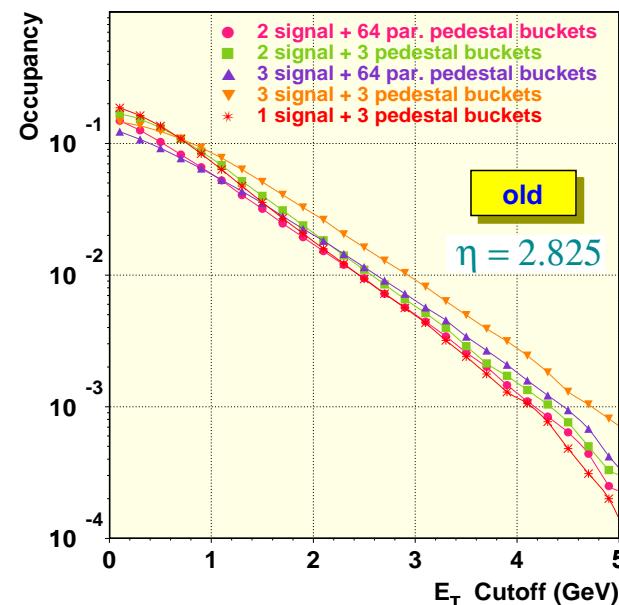
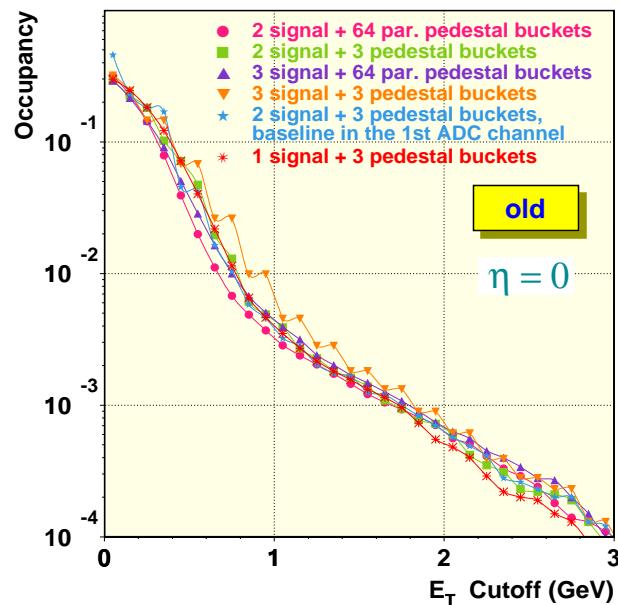
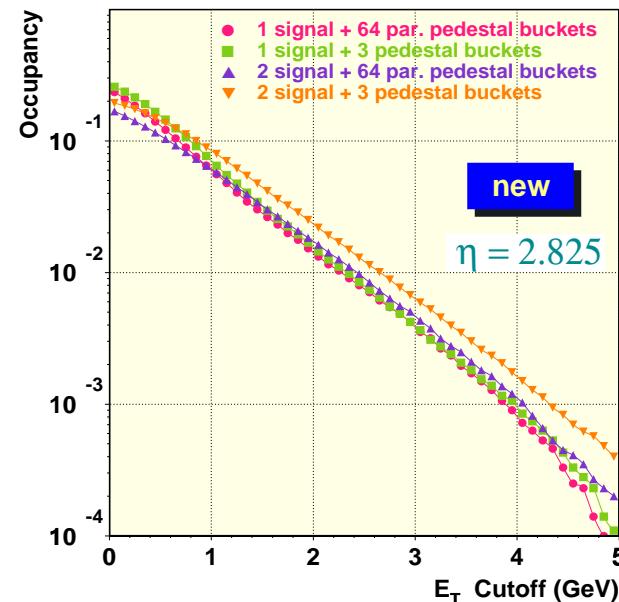
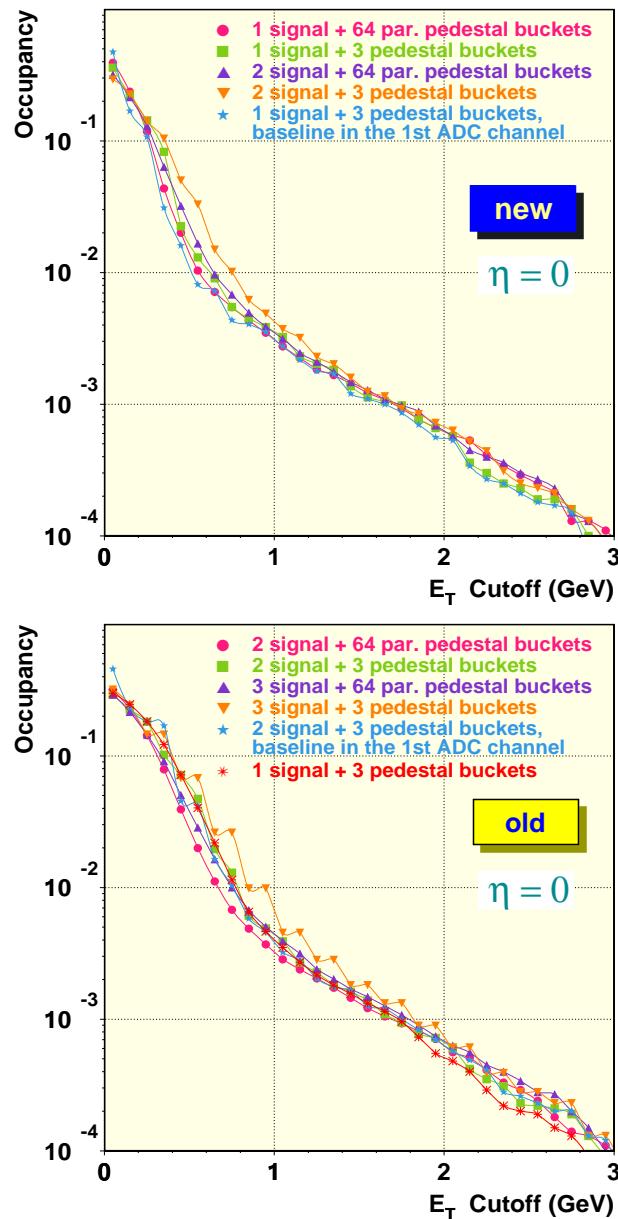


READOUT RESPONSE TO NOISE + PILEUP



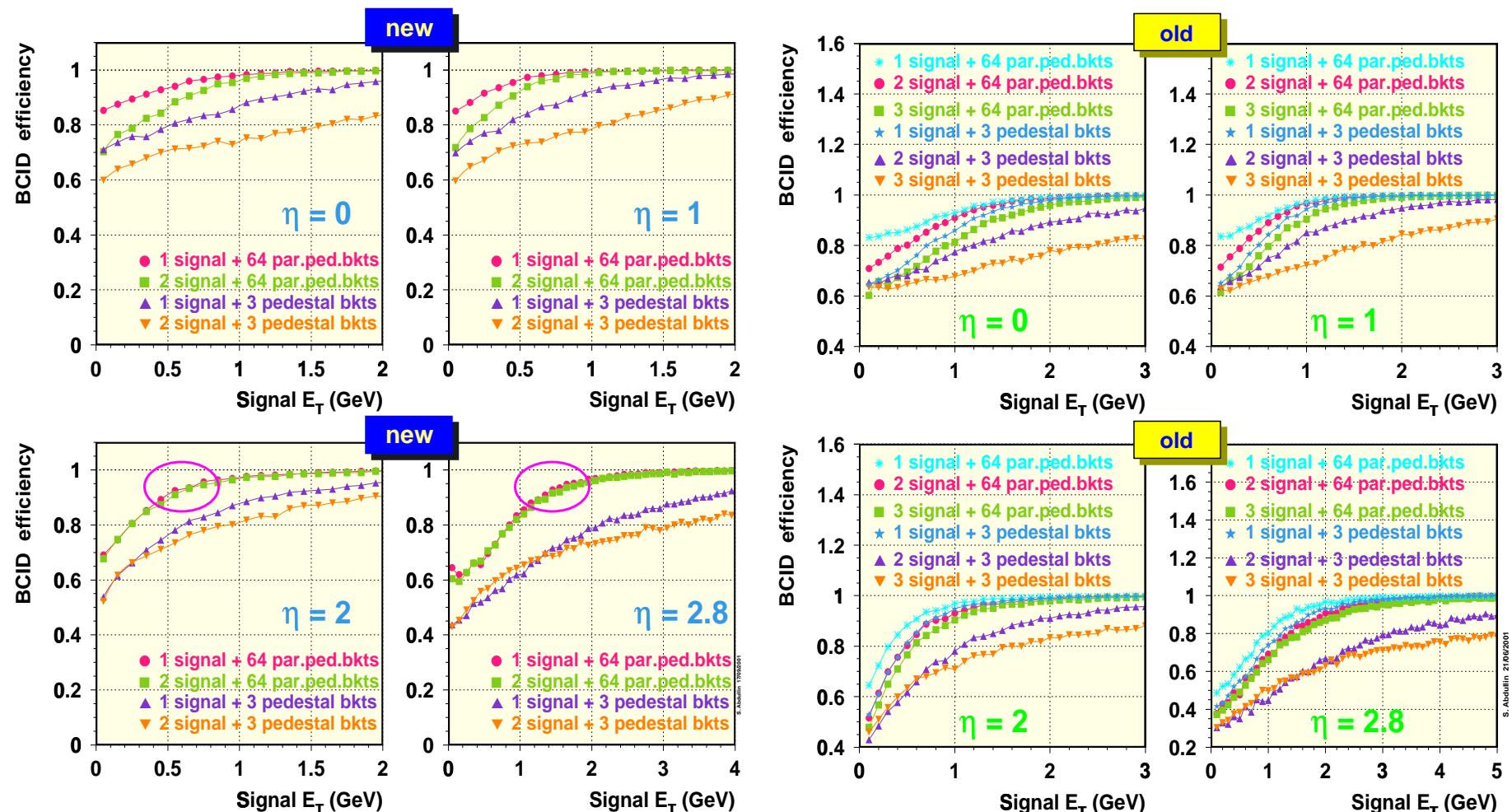
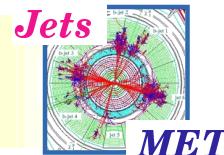


OCCUPANCY (NOISE + PILEUP)





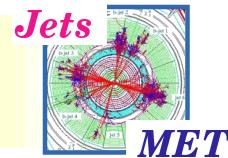
BCID IN CASE OF PILEUP



■ The smaller number of buckets - the better BCID



FE SIMULATION SUMMARY



- HCAL code in ORCA updated
- Clearly, the shorter is the signal - the better ...
 - signal resolution ● BCID ● occupancy
- Toy MC simulation without pileup :
 - 1,2,... bukets signal content is stable (~ 1%) within 5-6 ns provided time phase is properly tuned
 - 1-bucket collection yields better resolution for low energy signal than 2-buckets one (short signal)
 - idem for 2 vs 3 buckets (long signal)
 - photo statistics effect dominates over other resolution factors in case of high-energy signal (> 5 GeV) given fixed noise
- Toy MC simulation with pileup :
 - in terms of E_T the situation in HB is similar to no-pileup case
 - in HE pileup dominates (over noise)
 - BCID is better for 1-bucket collection mode (without presamples !)
- More conclusions (as a base for decisions) ...